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A CLIMATOLOGICAL STUDY VOLUME I: CONTINENTAL

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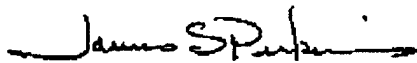
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PREFACE

This study was prepared by the Air Force Combat Climatology Center's Readiness Support Branch (AFCCC/DOJ), in response to a support assistance request (SAR) from the Air Force Global Weather Center (AFGWC), Offutt AFB, Neb.

The project would not have been possible without the dedicated support of the many people and agencies listed below. We appreciate the assistance of Mr. David Pigors, Mr. Charles Travers, Mr. Gary Swanson, Ms. Susan Keller, Ms. Susan Tarbell, Ms. Lisa Mefford, and Ms. Randa Simon of the Air Weather Service Technical Library. Without their help, much of the information in this document, necessarily obtained from multiple sources, would simply not have been made available to us.

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Chapter 1

INTRODUCTION

Area of Interest. This first of a two volume study describes the geography, climatology, and meteorology of continental East Asia. East Asia has been divided into two basic regions, the continental region and the maritime region. The continental region covers areas in East Asia with

little or no maritime influence on their weather regimes. The areas with maritime influences will be discussed in Volume II of this set. Continental East Asia area contains three “zones of climatic commonality” as shown in Figure 1-1 and further described on the next page.

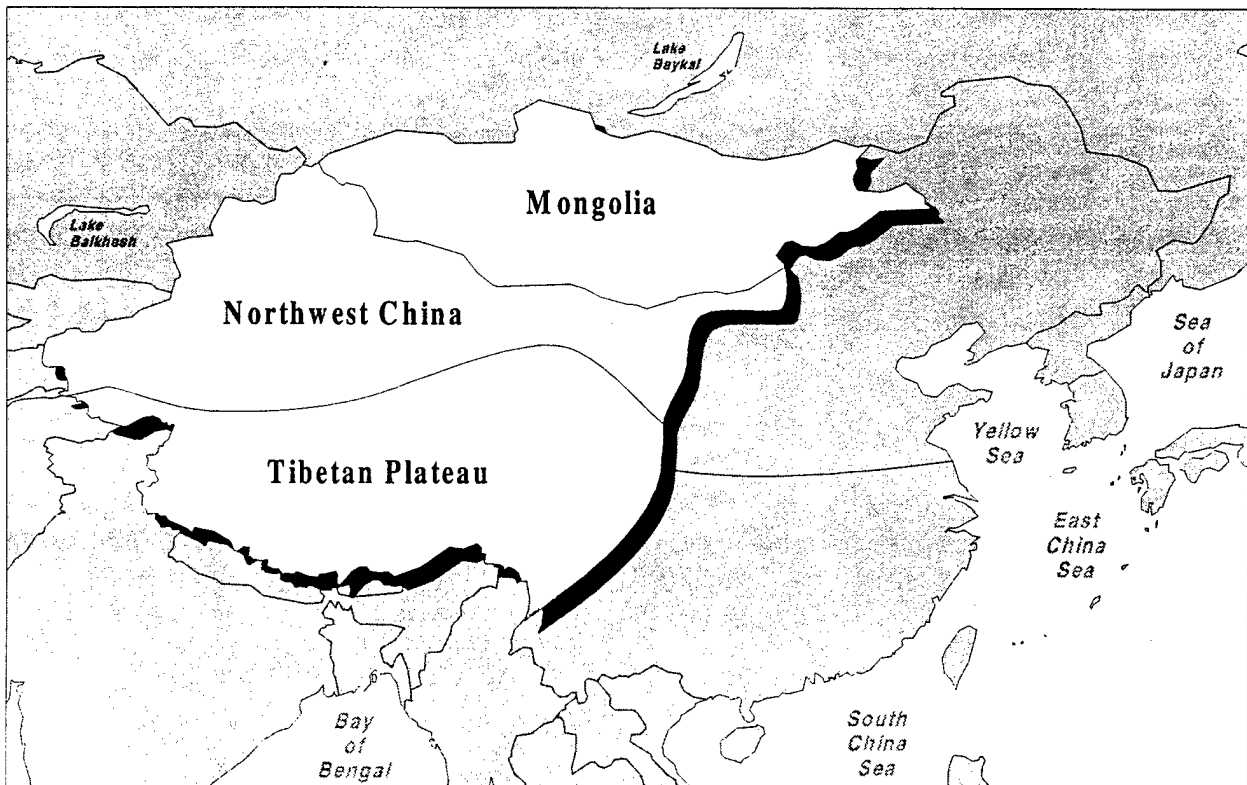


Figure 1-1. Continental East Asia and Its Three “Zones of Climatic Commonality.”

- **Tibetan Plateau.** The Tibetan Plateau includes the provinces of Xizang, Quinhai, western Sichuan, and extreme northern Yunnan. The northern boundary of the Tibetan Plateau begins along the northern border of the Xizang and Gansu provinces and includes the Kunlun and Altun mountains to the 5,900-foot (1,800-meter) elevation contour along the northern slopes. The eastern boundary follows the western border of the province of Gansu to the south and runs across the western third of Sichuan Province along the 103° E meridian and into northern Yunnan Province. The southern boundary follows the northern slopes of the Himalayas and borders the

countries of Myanmar (formerly known as Burma), India, Bhutan, and Nepal. The western boundary is bounded by the disputed territories of Kashmir and Jammu.

- **Northwest China.** The southern boundary of northwest China begins on the Sino-Indian border (35° N, 80° E) and extends northeast through the Kunlun Mountains approximately 110 miles (180 km) to the 5,900-foot (1,800-meter) elevation contour on the north rim of the Tibetan Plateau. From this point, the southern boundary follows the 5,900-foot (1,800-meter) contour eastward approximately 1,100 miles (1,800 km) to just west

of the city of Ching-T'ai. Extending northeastward, the eastern boundary follows the 200 mm annual isohyet (almost following the 4,600 feet (1,400 meter) elevation contour) approximately 700 miles (1,150 km) until it reaches the Mongolian border near Erenhot. The eastern boundary separates the eastern edge of the Gobi Desert from the Helan and Yin mountains and the Inner Mongolian Plateau. The northern boundary follows the Sino-Mongolian border westward through the Gobi Desert and the Altai Mountains until it reaches the point in extreme northwest China where China, Mongolia, Russia, and Kazakhstan meet. The western boundary of northwest China meanders southwestward as it follows the international borders between China and, in succession, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, and India. The last section of the western boundary follows the Chinese line of control through the disputed Sino-Indian border area to 35° N, 80° E.

- **Mongolia.** Mongolia is a landlocked nation located in north-central Asia between Russia and China. Mongolia is slightly larger than the state of Alaska. Of the 5,000 miles (8,100 km) that make up the total land boundary, nearly 60 percent of it is shared with China. The remainder (40 percent) is shared with Russia. Mongolia is located more than 400 miles (650 km) from the nearest bodies of water, Korea Bay and the Bay of Chihli. The Sea of Japan is more than 600 miles (900 km) from the easternmost tip of Mongolia.

Study Content. Chapter 2 provides a general discussion of the major meteorological features that affect continental East Asia. The features include semipermanent climatic controls, synoptic disturbances, and mesoscale and local features. The individual treatments of each region in subsequent chapters do not repeat descriptions of these phenomena; instead, they discuss specific effects of these features unique to that region. Therefore, meteorologists using this study should read and consider the general discussion in Chapter 2 before they try to understand or apply the individual climatic zone discussions in Chapters 3 through 5. This is particularly important because the study was designed with two purposes in mind—a master reference for East Asia and a modular reference to each individual region.

Chapters 3 through 5 amplify the general discussions in Chapter 2. They describe the geography, climate, and meteorology of the specific regions shown in Figure 1-1. These chapters provide detailed discussions of the regions that are known to feature reasonably homogeneous climatology and meteorology.

Each chapter first discusses geography (including topography, rivers and drainage systems, lakes and water bodies, and vegetation), major climatic controls, and if appropriate, special climatic features. Weather for each season is then discussed with the following elements highlighted:

- General Weather
- Sky Cover
- Visibility
- Surface Winds
- Upper-Air Winds
- Precipitation/Thunderstorms
- Temperature
- Additional Hazards

Conventions. The spellings of place names and geographical features are those used by the Master Station Catalog or the National Imagery and Mapping Agency (NIMA). In some cases, the spellings may vary ("i" and "y" are interchangeable) between reference sources. Distances and elevations are in feet and statute miles with conversions to meters or kilometers (km) as appropriate. Cloud and ceiling heights are in feet. When the term "ceiling" is used, it means 5/8 cloud coverage at and below any level unless otherwise stated. Temperatures are in degrees Fahrenheit (°F) with Celsius (°C) conversions. Wind speeds are in knots. Precipitation amounts are in millimeters (mm). Charts are labeled in Universal Coordinated Time (UTC) or Zulu (Z) time. Otherwise, local time (L) is used.

While the meteorological community has gone to the term "hectopascals" as the pressure unit, Air Force weather usage remains "millibars." Therefore, we have elected to remain with "millibars" (mb) for audience convenience.

Cloud bases are above ground level (AGL) and tops above mean sea level (MSL) unless specified

otherwise. Since cloud bases are generalized over large areas, readers must consider terrain in discussions of cloud bases in and around mountains.

Data Sources. Most of the information used in preparing this study came from two sources within AFCCC. Studies, books, atlases, and so on were supplied by the Air Weather Service Technical Library (AFCCC/DOL). Climatological data came directly from the Air Weather Service Climatic Data

Base, through OL-A, AFCCC—the division of AFCCC responsible for maintaining and managing this database.

Related References. This study, while more than ordinarily comprehensive, is certainly not the only source of climatological information for the military meteorologist concerned with East Asia. Staff weather officers and forecasters are urged to contact the AWS Technical Library for more data on the study area.

Chapter 2

MAJOR METEOROLOGICAL FEATURES OF CONTINENTAL EAST ASIA

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SEMIPERMANENT CLIMATIC CONTROLS

Continental Pressure Features. These features include the Asiatic high, the Australian high, the west China trough, and several heat lows.

Asiatic (Siberian/Mongolian) High. The Asiatic high is a strong, but shallow high-pressure cell that dominates much of the Asian continent from late September to late April. It is the strongest cold anticyclone in the Northern Hemisphere and rarely extends above 850 mb. It is normally overlaid by westerlies aloft. The mean central pressure is strongest (1,038 mb) in January, when the high is centered over western Mongolia (see Figure 2-1).

The Asiatic high is created and supported mainly by radiational cooling. Migratory arctic air masses temporarily reinforce and intensify the high, producing multiple centers. The central pressure occasionally exceeds 1,050 mb for up to 3 days; the highest recorded pressure is 1,083 mb. Variations in the high result in a 10- to 12-day periodicity in the strength of the northeast monsoon.

West China Trough. The Asiatic high tends to form two ridges. One points southeastward to the Chinese coast and Taiwan; the other stretches southwestward along the eastern Indian coast to merge with the

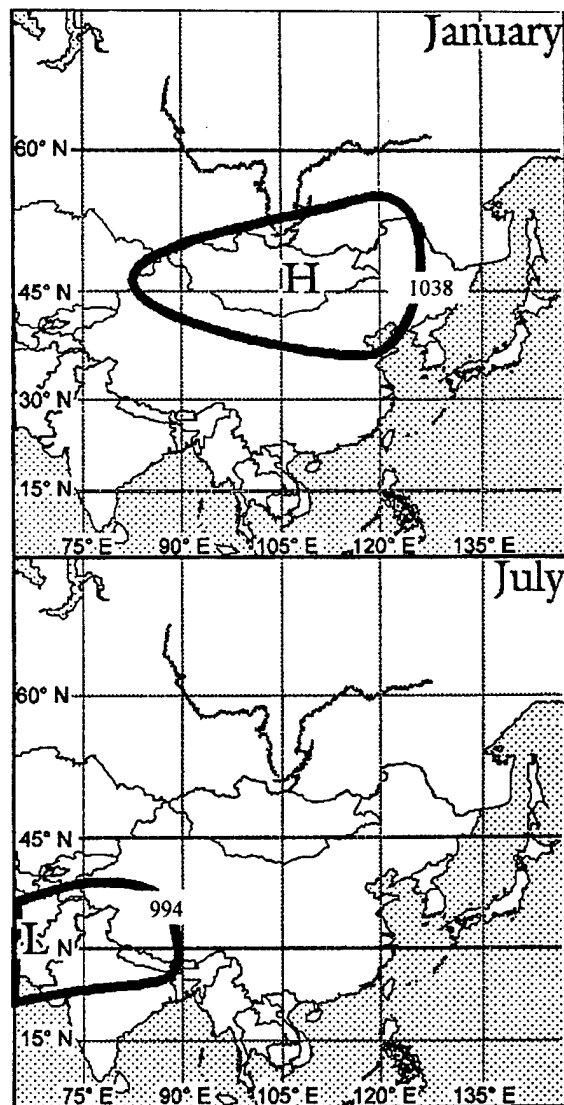


Figure 2-1. Major Continental Pressure Features. Top, Asiatic high; bottom, Asiatic low.

Indian high. Between these two ridges lies the broad, west China trough that stretches from central Myanmar (formerly known as Burma) to southwestern China. The lee-side effects of the Tibetan Plateau intensify this trough. Active cold surges often occur when this trough is weak.

Asiatic (Pakistani Heat) Low. From May to early October, this low anchors the eastern end of a broad, low-level thermal trough extending from

northwestern India across southern Pakistan, Iran, Saudi Arabia, and into the Sahara. The low, which is normally cloud-free, is strongest in July when its central pressure averages 994 mb. Its mean position in July is near 35° N, 65° E (see Figure 2-2). This thermal low draws in the monsoon trough and anchors its western end. Flow around the Tibetan Plateau dynamically enhances the troughing in India.

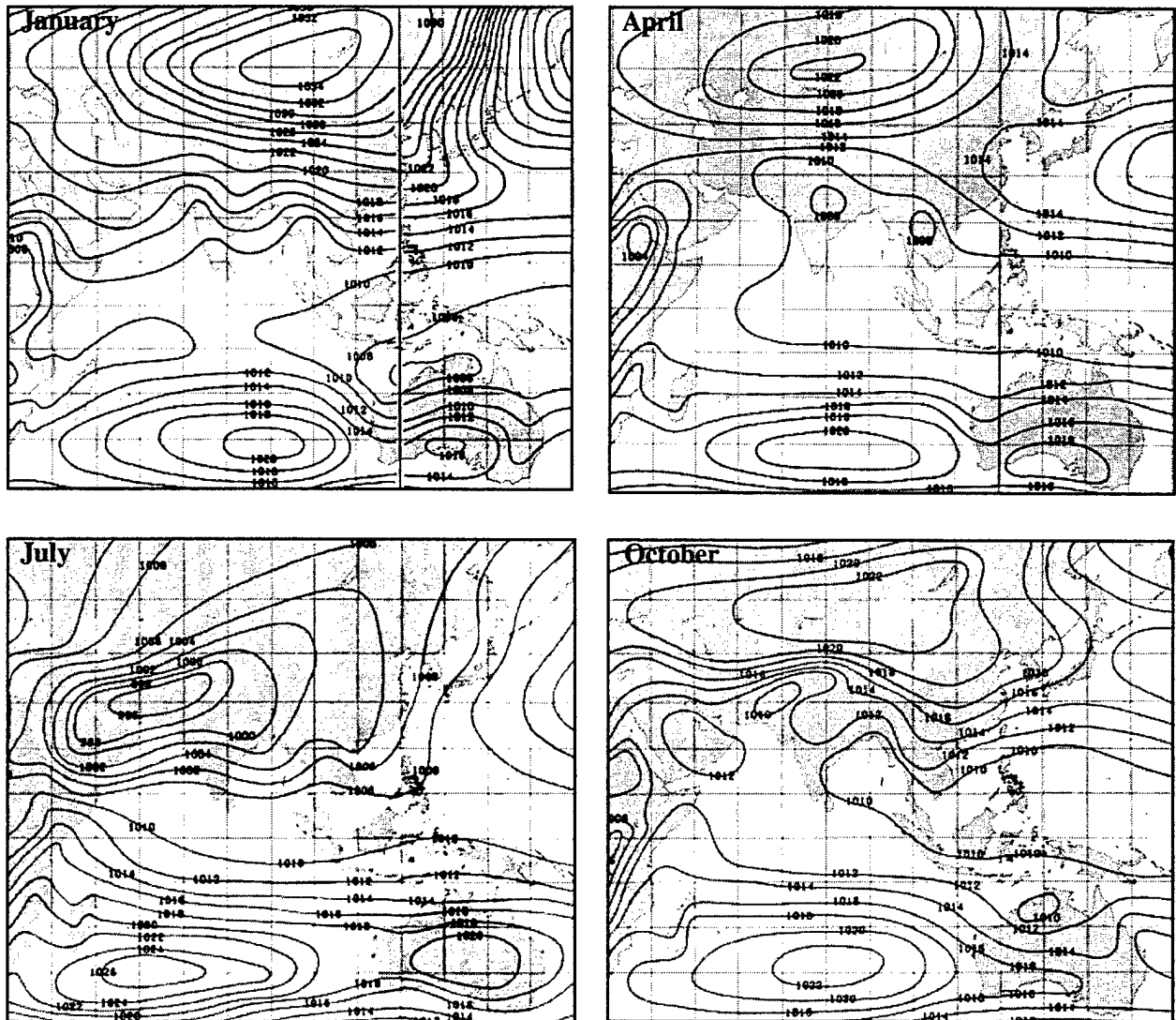


Figure 2-2. Mean Sea-Level Pressure for January, April, July, and October. The figure shows the position of the major pressure systems and how they migrate from season to season.

SEMIPERMANENT CLIMATIC CONTROLS

Maritime Pressure Feature.

Aleutian Low. The Aleutian low sits over the Aleutian Islands in the North Pacific and affects East Asia primarily during the winter monsoon. It reaches its maximum strength in January with a central pressure near 996 mb (Figure 2-3). Eastward

moving storms tend to converge in this area, especially during winter. The Aleutian low acts with the Asiatic (Siberian) high to establish a strong pressure gradient over East Asia. The strength of this pressure gradient is directly related to the strength of the winter (northeast) monsoon experienced by much of Asia.

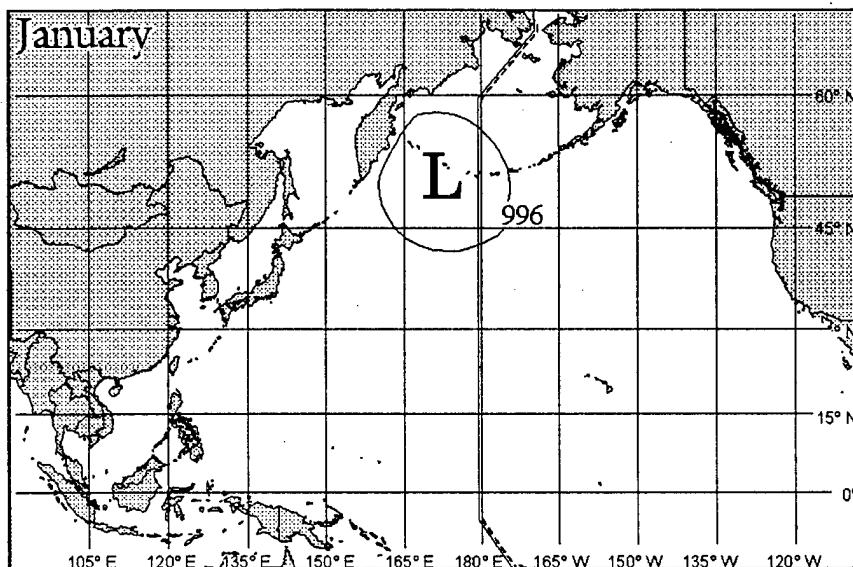


Figure 2-3. Major Maritime Pressure Feature. The figure shows the January position of the Aleutian low.

Monsoon Climate. During the Northern Hemisphere winter, the warm oceanic ridge and the Asiatic high work together to form a continuous belt of high pressure. During summer, heat lows replace the Asiatic high. This seasonal reversal of the pressure gradient gives rise to the northeast and southwest monsoons that affect East Asia. The term "monsoon" is commonly applied to those areas of the world where there is a seasonal reversal of prevailing winds, but the generally accepted definition of a monsoon climate includes satisfaction of these four criteria:

- The prevailing seasonal wind direction shifts by at least 120 degrees between January and July,
- Wind speeds must equal or exceed 6 knots (3 m/s) at least one of the two seasons,
- Fewer than one cyclone-anticyclone alternation occurs every 2 years in either month in a 250 x 250 NM (500 x 500 km) square.
- The average frequency of prevailing wind direction in January and July exceeds 40 percent.

Winter (Northeast) Monsoon. The winter monsoon occurs when the monsoon trough migrates to the south during the Northern Hemisphere winter. When this occurs, outflow from the Asiatic high dominates the region. Stable weather and cold, northeasterly winds typify the winter monsoon. It is also characterized by a succession of cold air surges that sometimes brings freezing temperatures as far south as Hong Kong. The cold outbreaks are often accompanied by high winds, sharp temperature drops, freezing rain, heavy snowfalls, severe frost, and sandstorms. Figure 2-4 shows the usual positions of the polar front and monsoon trough during the winter monsoon. Figure 2-5 shows a cross section of the wind flow during the winter monsoon.

The onset of the winter monsoon is abrupt and

rapidly moves southward. It penetrates northeastern China in early September and reaches Hainan Island by the second week in October. The pressure field over the Asia Pacific region quickly reverses in September as the Asiatic low weakens, and the pressure over East Asia increases slightly. The dynamic effect of the Tibetan Plateau plays a significant role in the rapid movement of the winter monsoon into southern China.

By the end of October, the winter monsoon is firmly in place. The winter monsoon circulation reaches its maximum development in January when the Asiatic high is at full strength and the Aleutian low is well-established. The circulation pattern gradually weakens from February through March. The winter monsoon's end, in April (south) and May (north), comes as the monsoon trough moves north. The subtropical jet moves north of the Tibetan Plateau, while the Tibetan high and tropical easterly jet establish themselves. Precipitation is at a minimum over continental East Asia during the winter monsoon.

Summer (Southwest) Monsoon. The summer monsoon season develops in response to the northward movement of the subtropical high pressure ridge in the western Pacific. The onset of the monsoon starts in early May over the northern part of the South China Sea and ends in late July over northern China. The southwest monsoon has very little impact on continental East Asia due to the high terrain that exists along the Tibetan Plateau.

As the subtropical ridge moves northward and strengthens, changes in the circulation pattern over the region takes place. The cold, dry high-pressure system over Mongolia is replaced by a large thermal trough. The subtropical westerly jet moves north of the Tibetan Plateau and gradually decreases in intensity. The Tibetan high moves onto the plateau, and the tropical easterly jet sets up south of the Himalayas. In the meantime, the monsoon trough moves northward into the South China Sea. Figure 2-6 shows the usual positions of the polar front and monsoon trough during the summer monsoon. Figure 2-7 shows a cross section of the wind flow during the summer monsoon.

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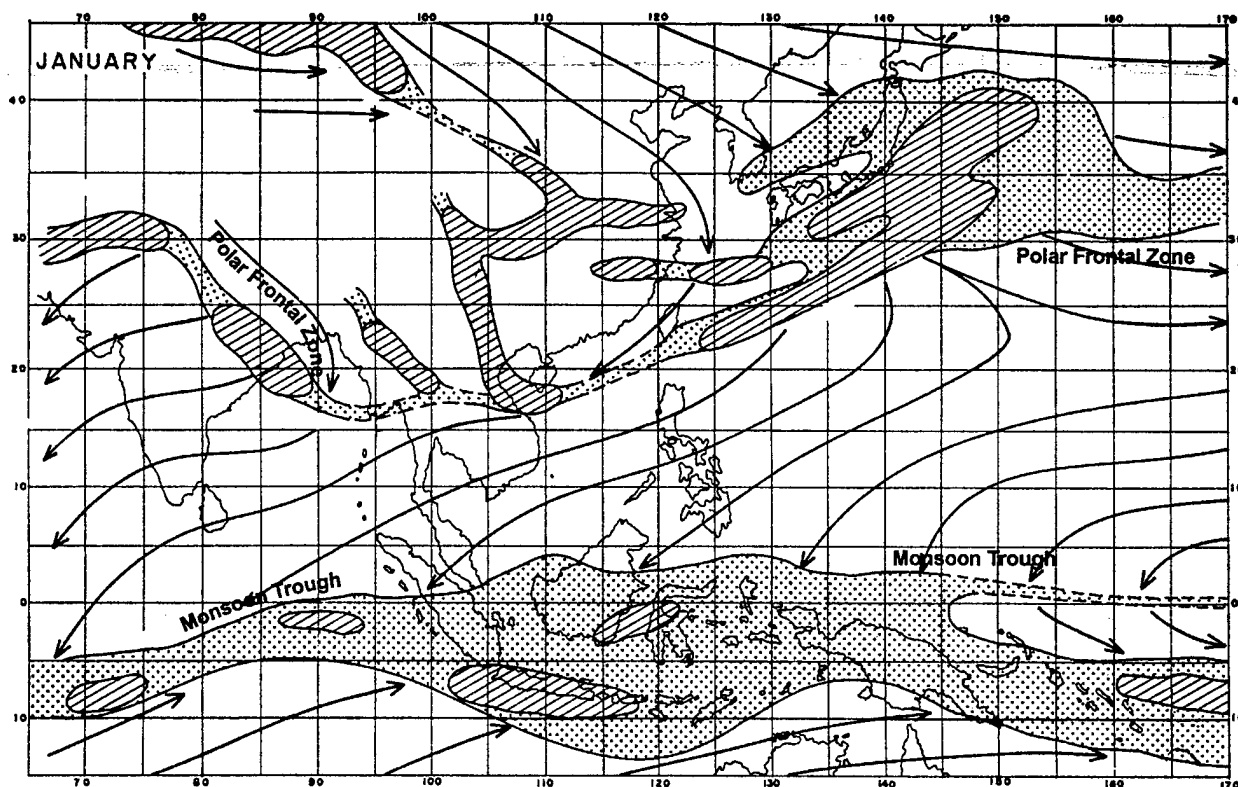


Figure 2-4. January Mean Position of Monsoon Trough and Polar Frontal Zones. Arrows represent steady winds; stippled and hatched areas show where the wind is more variable.

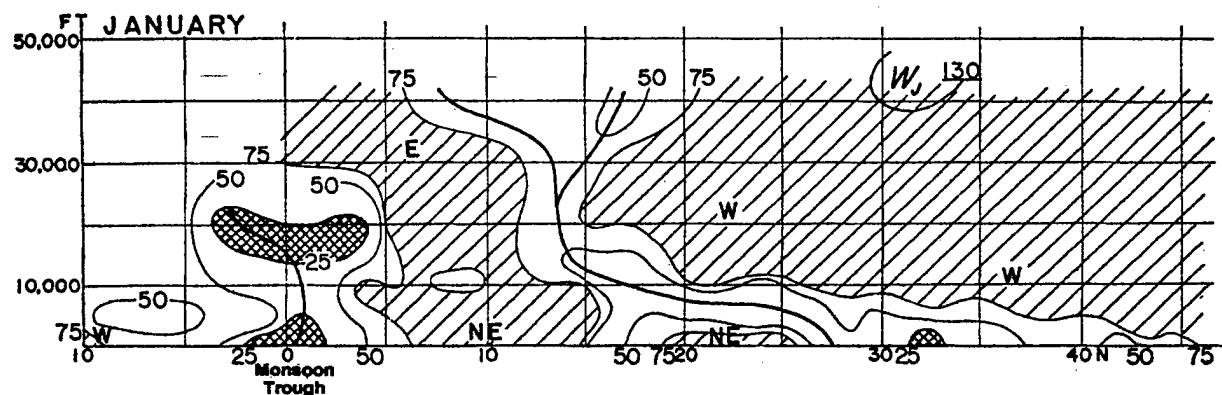


Figure 2-5. January Vertical Cross Section along 120° E. Striped areas show regions where the wind direction is steady (75 percent or more of the time). This includes the region of northeasterly winds near the surface at 25° N. Crosshatched areas show where the wind direction is variable, indicating a shear zone. Regions where the wind direction is least steady are shown as thin lines. The heavy lines can be interpreted as polar frontal zones or the monsoon trough.

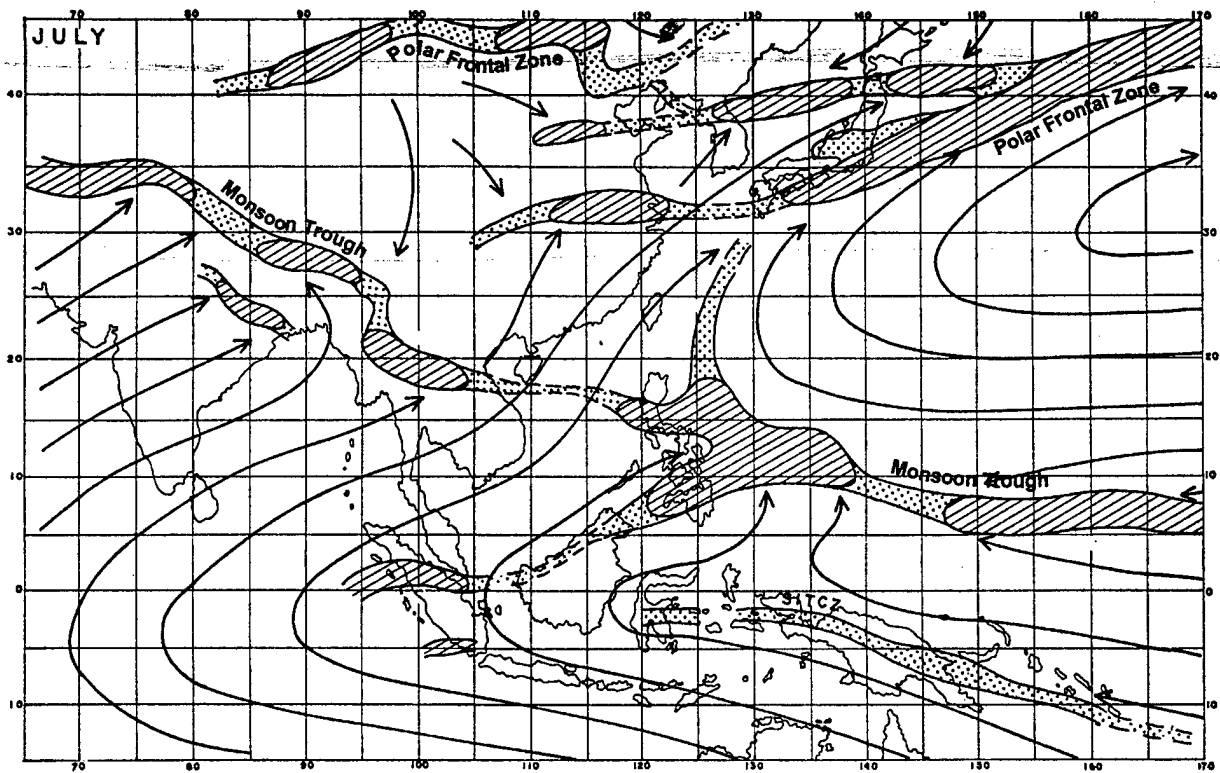


Figure 2-6. July Mean Position of Monsoon Trough and Polar Frontal Zones. Arrows indicate the mean wind flow direction; stippled and hatched areas show where the wind direction is more variable.

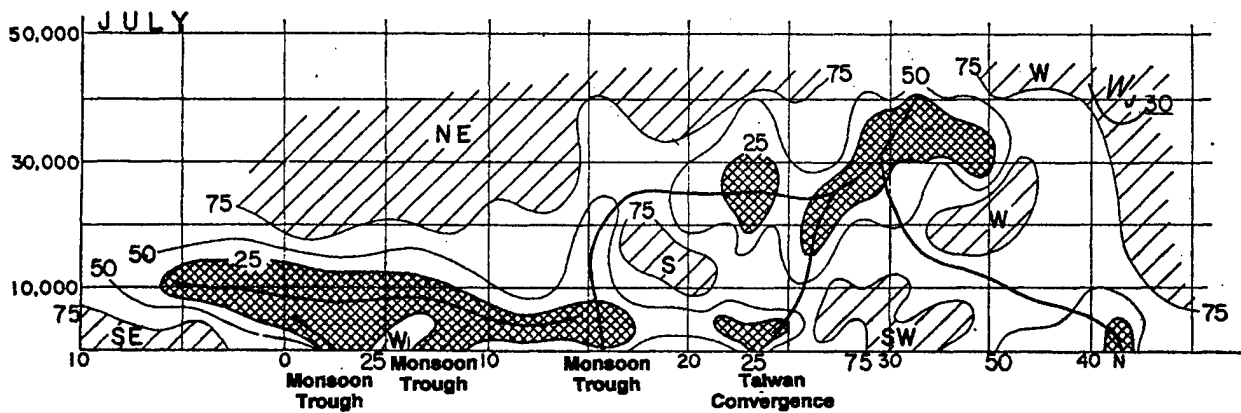


Figure 2-7. July Vertical Cross Section along 120° E. Striped areas show regions where the wind direction is steady (75 percent or more of the time). Crosshatched areas show where the wind direction is variable, an indication of a shear zone. Regions where the wind direction is least steady are shown as thin lines. The heavy lines can be interpreted as polar frontal zones or the monsoon trough.

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Jet Streams. The following jet streams affect this region: the polar jet, the subtropical jet, the tropical easterly jet, and the low-level jet.

Polar Jet. The presence of the polar jet is most evident during the winter season when the westerlies are at their strongest and have shifted to their most southern point. During the winter, the Tibetan Plateau splits the westerlies into two branches. The northern branch becomes the polar jet. Movement of the polar jet will vary widely between 45° and 70° N. It also merges with the subtropical jet in the vicinity of Japan to create a broad, deep band of very high wind speeds over eastern Asia. Wind speeds over the region have been measured at over 240 knots. During the summer, the polar jet shifts to the north and weakens. It is associated with the migratory lows and polar fronts. The polar jet follows the mean storm tracks very closely.

Subtropical Jet. In winter, the subtropical jet is situated south of the Himalayas and stretches

northeastward across south-central China. It crosses the coast near Shanghai to merge with the polar jet in the vicinity of Japan. This confluence zone enhances cyclogenesis in the South China Sea. This jet marks the southern limit of the winter polar air. It shows 2-3 degrees of latitudinal variation from the time it makes its first appearance over southern China in October until mid-April when it begins to shift back to the north (a prerequisite for the start of the summer monsoon). In the summer, it is located north of the Tibetan Plateau. Figure 2-8 shows the mean position of the subtropical jet at different times of the years. Mean positions range from 22° N in January to 45° N in July. Mean heights and speeds of the jet over East Asia are shown in figures 2-9a and 2-9b. These figures also denote the zones of the predominate storm tracks and the areas of maximum precipitation in the region.

Tropical Easterly Jet (TEJ). This Northern Hemisphere summer jet is one of the most important components of the summer monsoon system in the

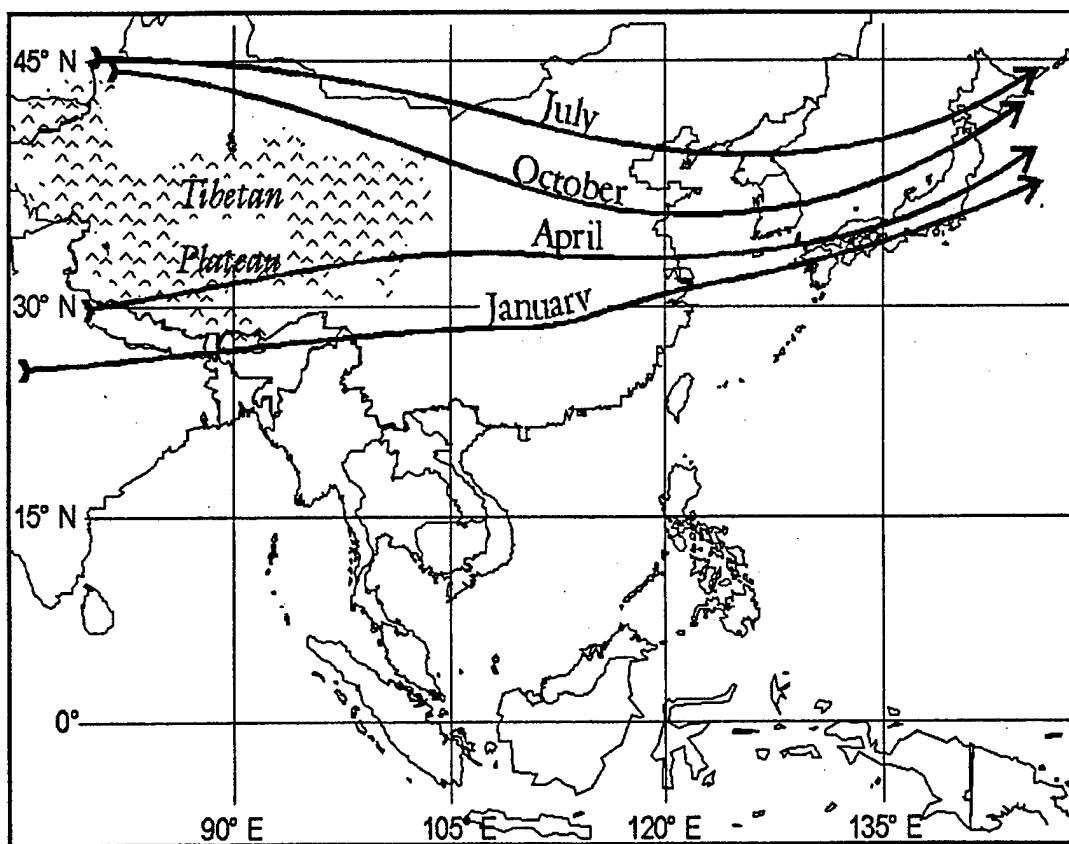


Figure 2-8. Mean January, April, July, and October Positions of the Subtropical Jet. The figure shows the mean position of the subtropical jet at different times of the year.

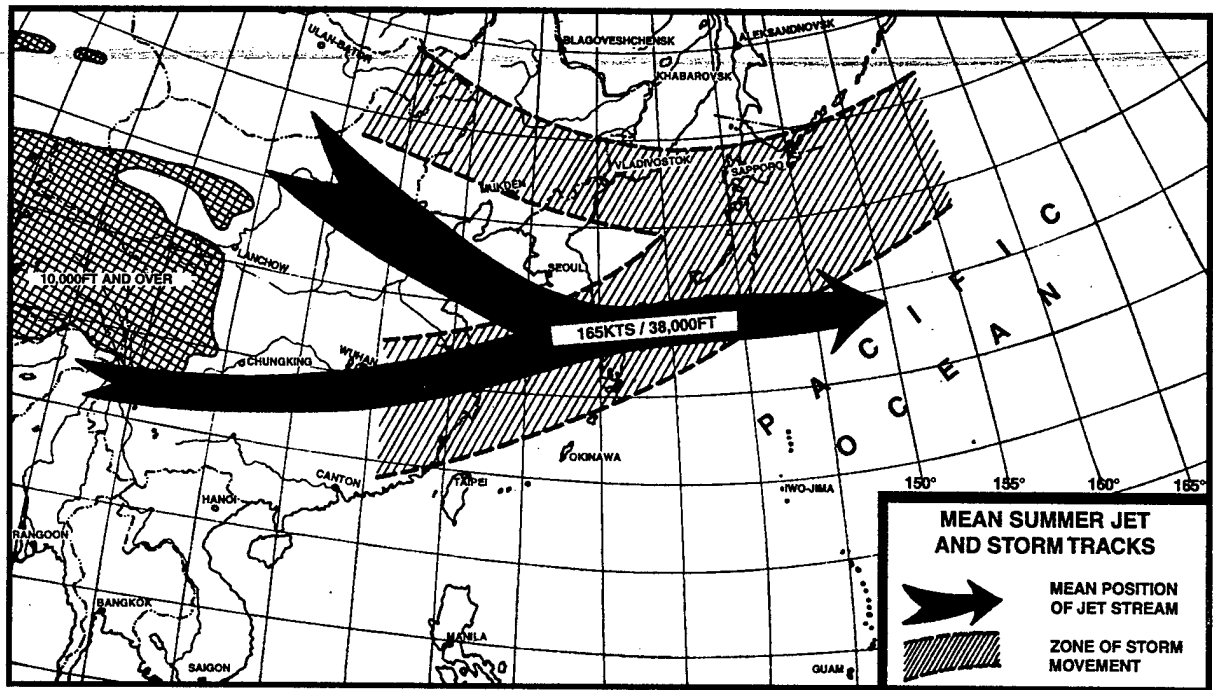


Figure 2-9a. Mean Position of Axes of Maximum Winds Superimposed over Zones of Extratropical Cyclone Movement for the Winter Season. Tibetan Plateau area with an elevation of 10,000 feet or higher is shown by checked area. Wind speeds may reach 186 knots at 38,000 feet.

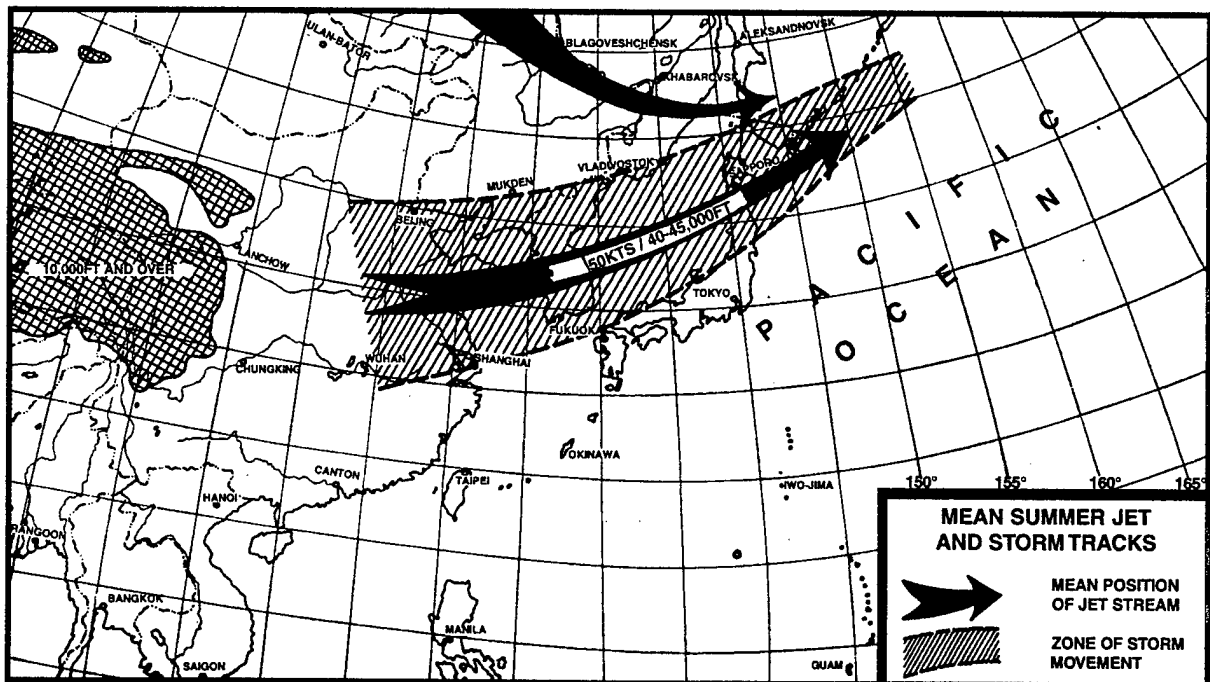


Figure 2-9b. Mean Position of Axes of Maximum Winds Superimposed over Zones of Extratropical Cyclone Movement for Summer Season. Wind speeds can reach 60 knots at 40,000 to 45,000 feet. Tibetan Plateau area with an elevation of 10,000 feet or higher is shown by checked area.

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East Asian monsoon region. It is also one of the major circulation features in the tropical upper troposphere in the northern summer. Its establishment and activity are closely associated with the seasonal change in the upper troposphere of the Northern Hemisphere (specifically, the development of the Tibetan anticyclone). The entrance region for this jet is over the South China Sea or in the western Pacific Ocean as far east as Guam (about 140° E). The mean position lies about 15° N latitude, 4 to 5 degrees south of the surface monsoon trough, but it oscillates between 5° and 20° N (see figure 2-10).

The jet has two branches over the region. The northern branch occurs at 10° to 20° N at 100 mb, and the southern branch occurs around 5° N at 150 mb (see Figure 2-11). The northern branch is generally the stronger of the two. The tropical easterly jet is very steady; the variability of its core

position is rather small. This jet is most persistent during the summer.

The tropical easterly jet is one of the most important circulation features affecting the monsoon activities and precipitation in East Asia. The variability of monsoon precipitation appears to be associated with the variation of the strength of the jet. A 10-year study of rainfall data showed the years with many monsoon rainfalls tend to correspond with a tropical easterly jet of above-normal intensity (a more extensive region of easterly wind speeds that exceed 40 knots, a more northerly position of the jet axis, and a stronger jet core). The years with deficit monsoon rainfalls tended to correspond with a tropical easterly jet of below-normal intensity. The study also indicated a variability period of 2-3 years for the jet with a corresponding variability for the precipitation patterns.

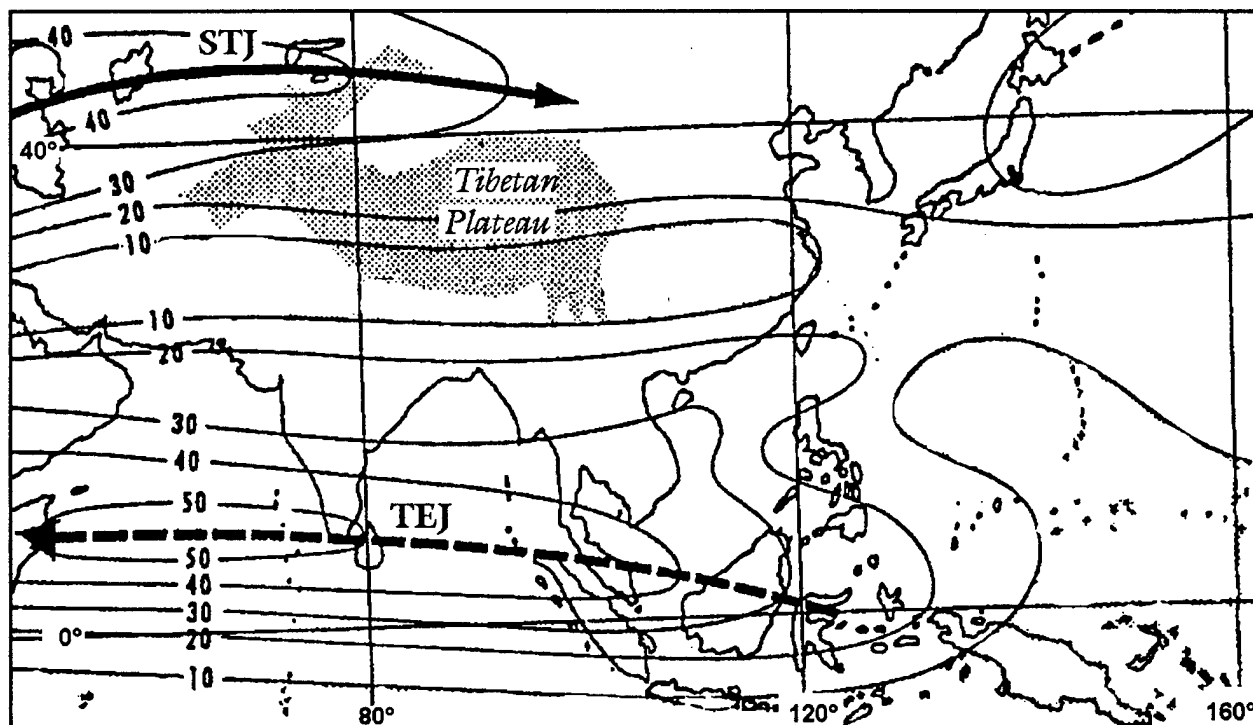


Figure 2-10. Mean July Position of the Tropical Easterly Jet. Wind speed in knots.

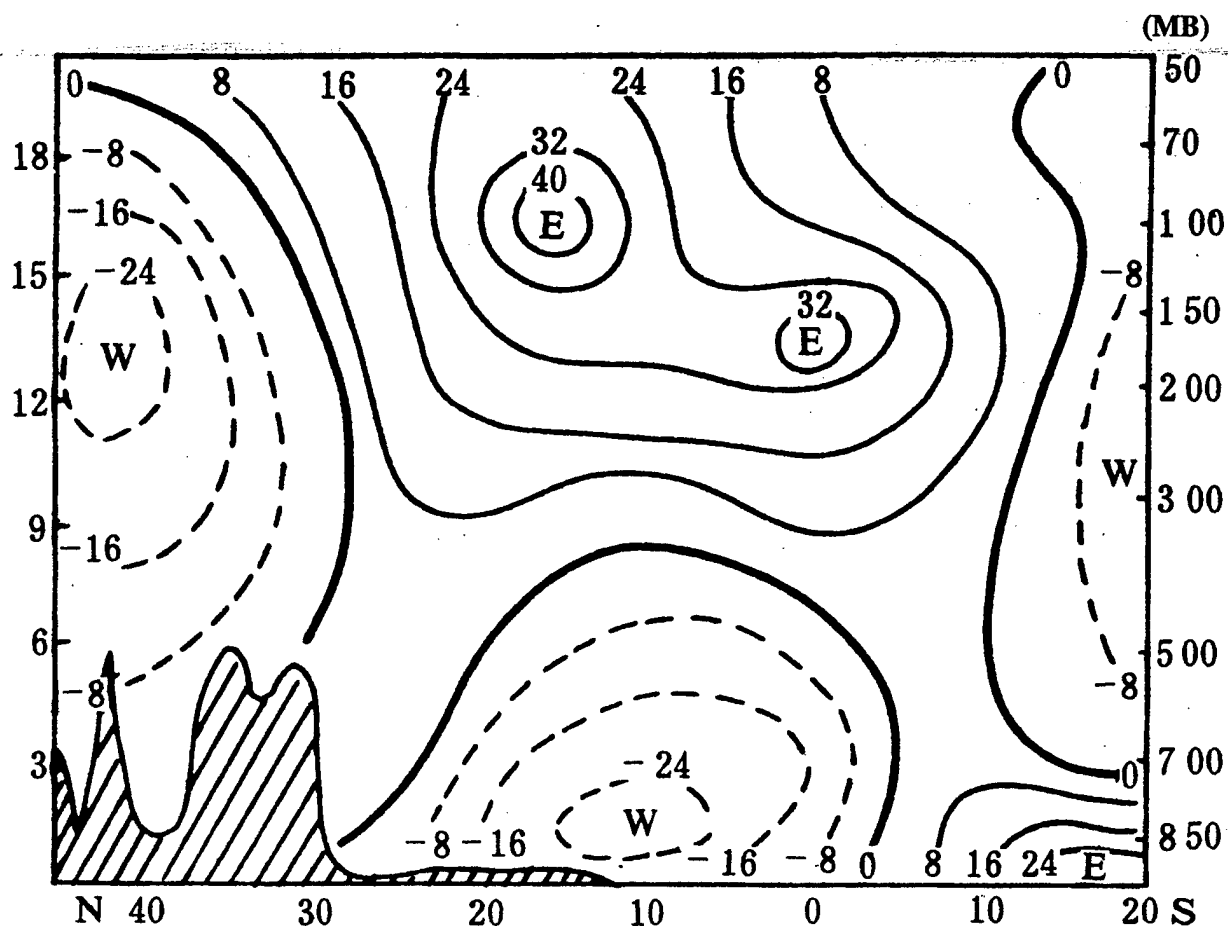


Figure 2-11. A Cross Section of the Mean Zonal Wind Components along 80° E for July. Solid (dashed) lines denotes isotach of easterly wind (westerly wind). Units: m s^{-1} .

Mid- And Upper-Level Flow Patterns

Figures 2-12 through 2-15 show January, April, July, and October mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

High pressure dominates the region at the 850-mb level during January (see Figure 2-12) with high-pressure centers located over Mongolia and off the southeast coast of China. The southerly winds situated to the west of the high off the coast of China pulls warm air over southern China, inducing a baroclinic zone. This zone causes the strong cold surges typical of the winter monsoon. These surges push into the Gobi desert and are funneled westward into the Takla Makan desert. The cold surges have little effect on the Tibetan Plateau. A high-pressure ridge exists at 700 mb, while strong westerly winds dominate the upper levels (500- and 200-mb). The subtropical ridge is at its southern most position.

By April there is a weakening in the high-pressure area over the mainland at the 850-mb level (see Figure 2-13). The subtropical ridge has

also begun its northward movement. Although strong westerly winds still exist at the upper levels, they are beginning to recede to the north.

July's pattern (see Figure 2-14) shows the location of the subtropical ridge around 30° N while the upper-level westerlies have receded and weakened. At the 200-mb level, the Tibetan high has set up and the tropical easterly jet is established. A southerly wind flow has set up in the lower levels, indicating the establishment of the summer monsoon. However, the high terrain of the Himalaya and Chin Ling mountains, and the Greater Khingan Range greatly reduce its effect on continental East Asia.

October's pattern (see Figure 2-15) shows the beginning of the transition to the winter season. High pressure begins to set up at the 850-mb level, while the subtropical ridge axis starts its southward movement. The upper-level westerlies begin to strengthen once again as they expand southward. At 200 mb, the Tibetan high is displaced and the tropical easterly jet has dissipated.

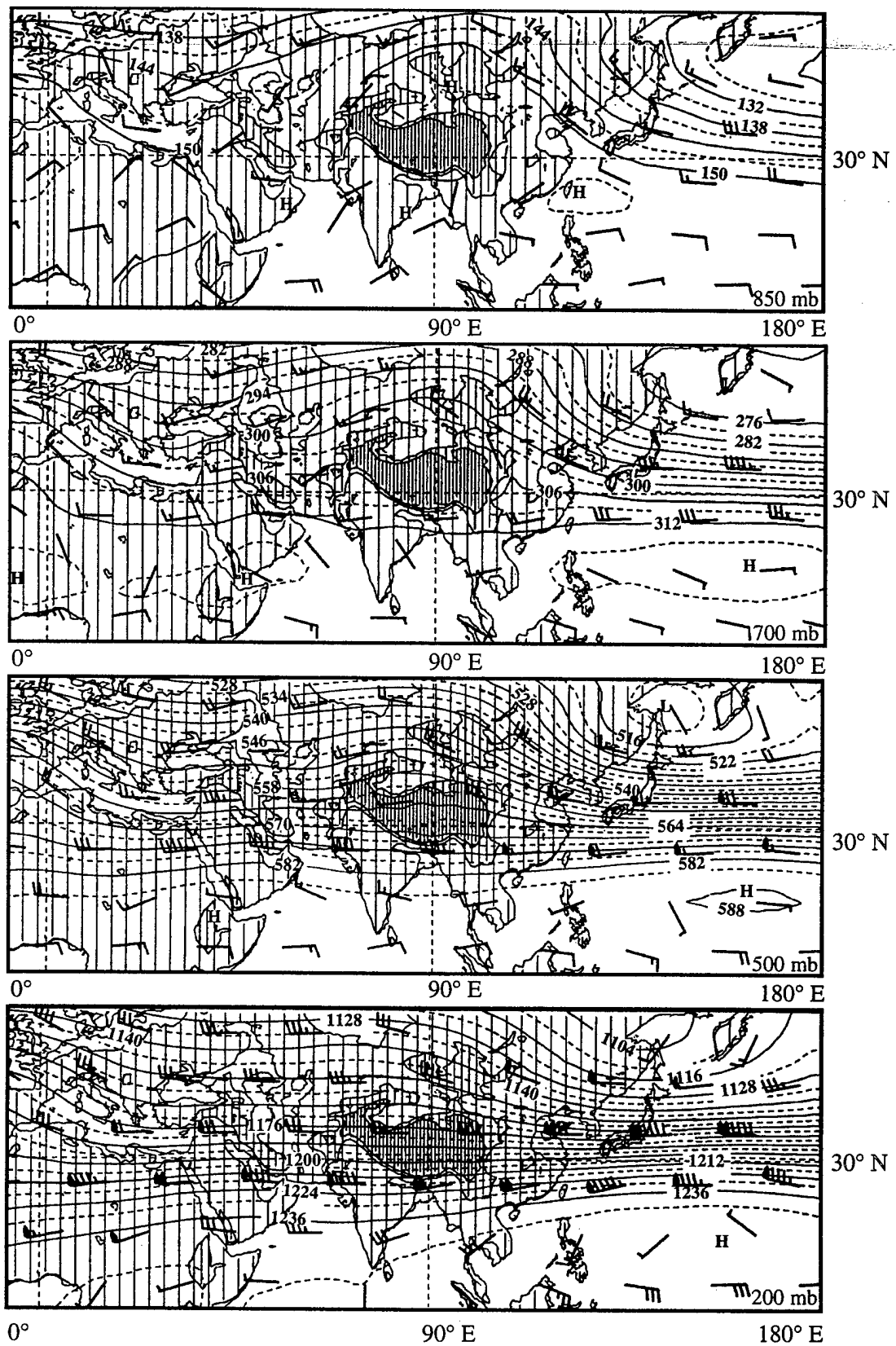


Figure 2-12. January Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

SEMIPERMANENT CLIMATIC CONTROLS

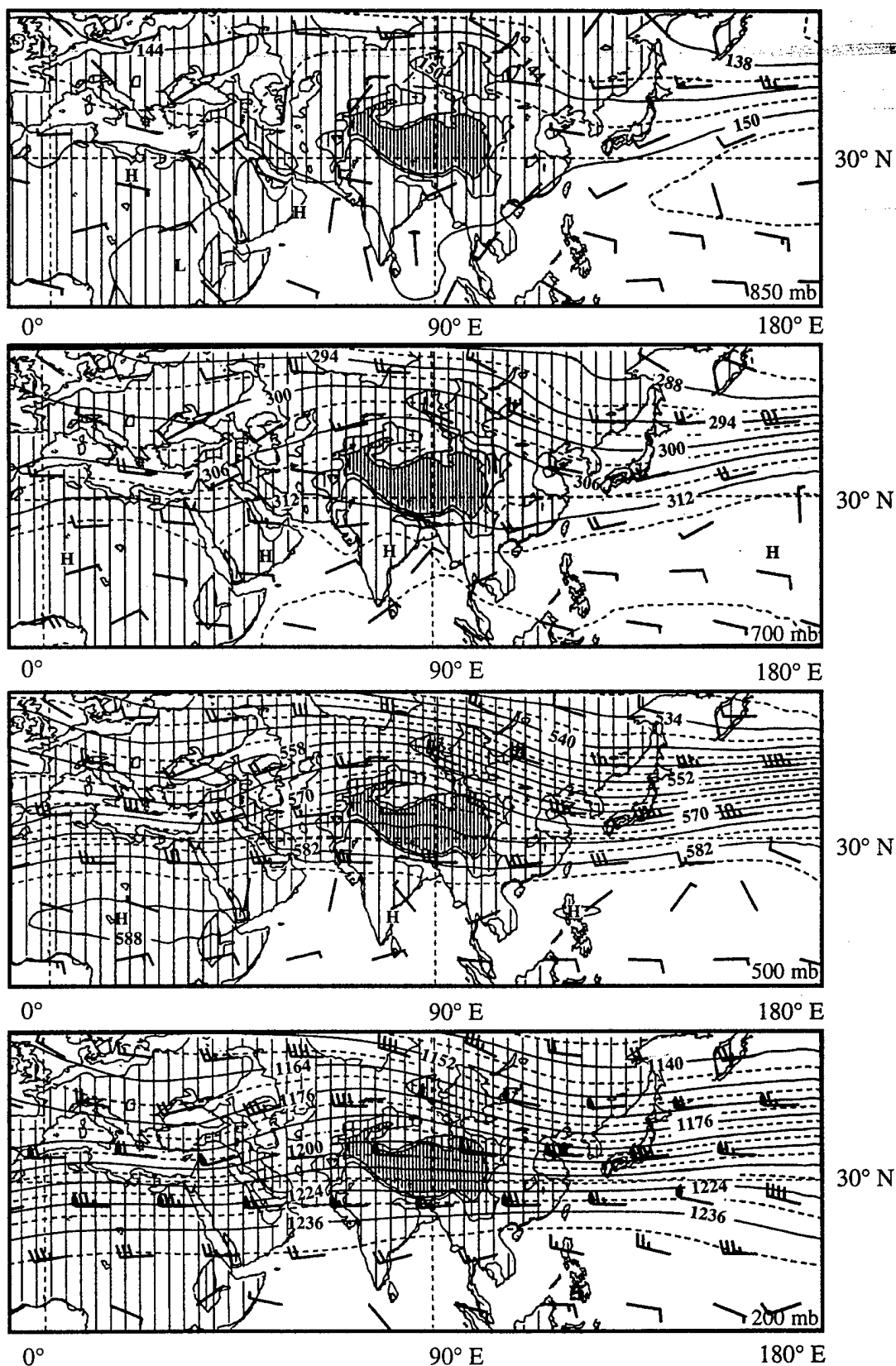


Figure 2-13. April Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

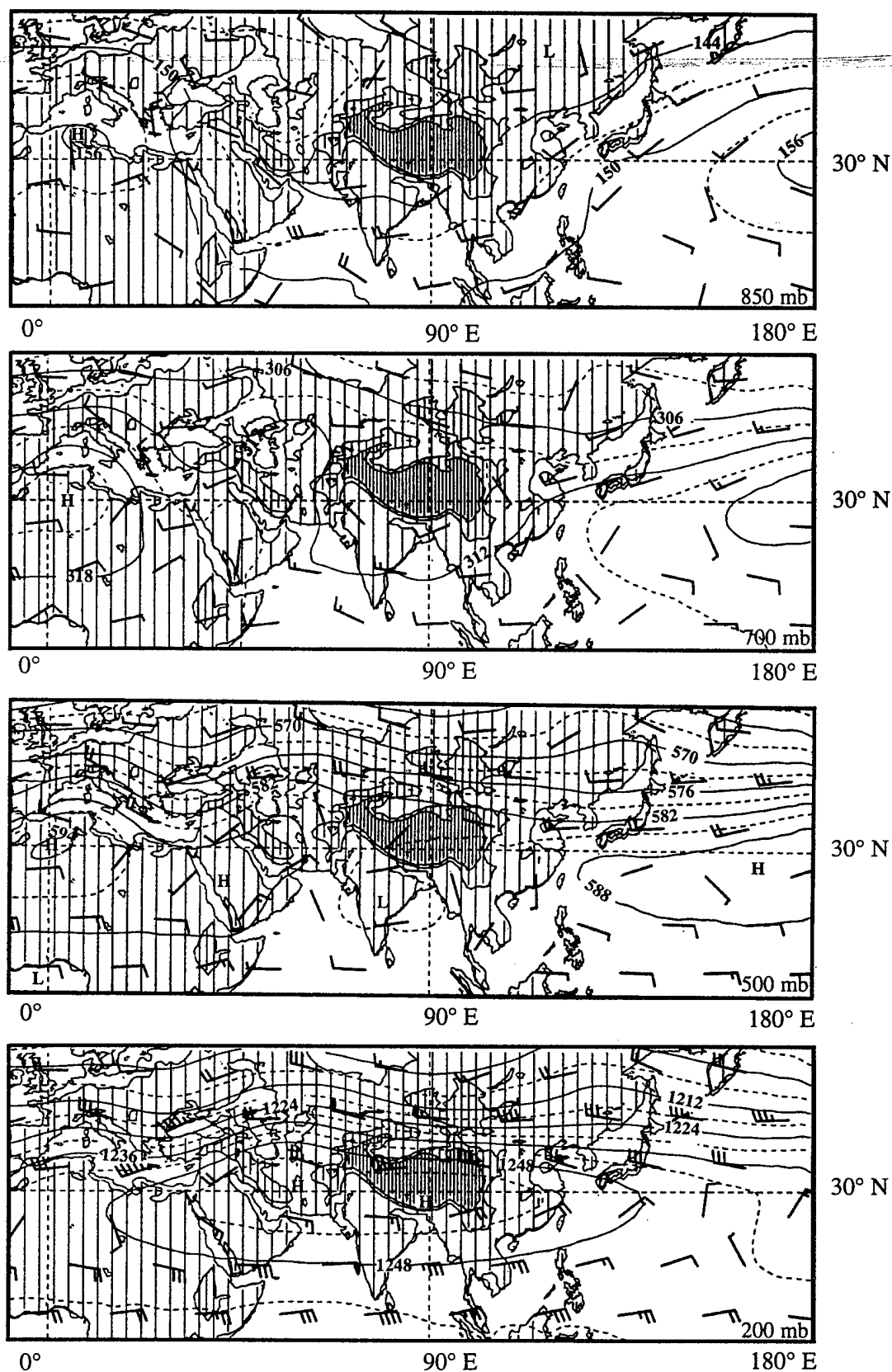


Figure 2-14. July Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

SEMI-PERMANENT CLIMATIC CONTROLS

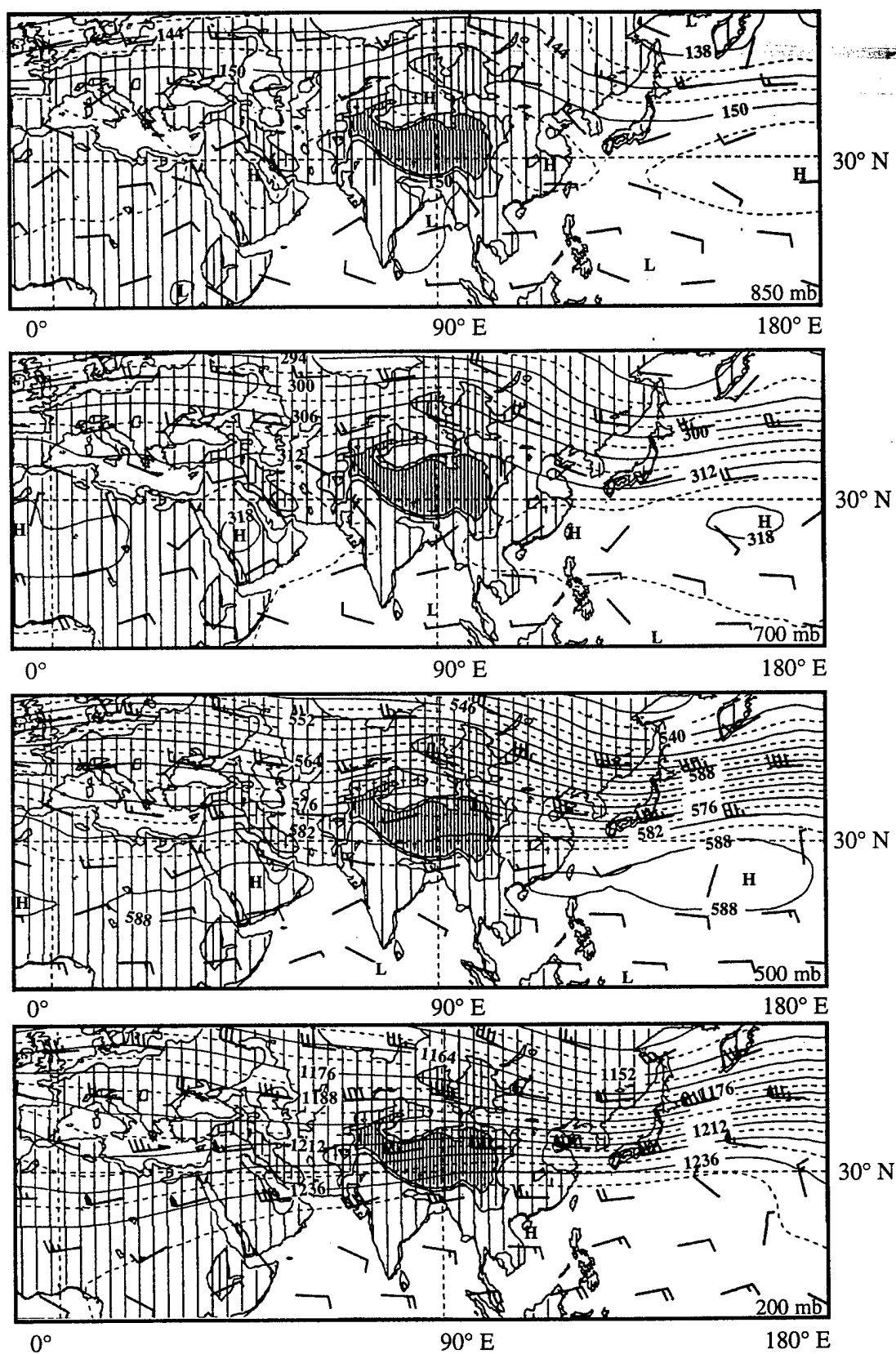


Figure 2-15. October Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

Subtropical Ridges. Subtropical ridges are upper-level features north and south of the equator with easterly flow between them. Mean annual positions are at 15° N and 10° S, centered at about 130° E. They move north-south together with the sun. The ridges are important as they provide outflow for the monsoon trough and tropical cyclone convection and provide a steering mechanism for tropical cyclone movement. Ridge movement is also one of the components needed for the transition between winter and summer monsoons (southward for winter, northward for summer). Ridge location can also impact rainfall during the summer monsoon. Studies have shown that droughts can occur over the Asian continent, particularly northern China, if the subtropical ridge is positioned farther west and/or to the south than normal. This abnormal movement cuts off the inflow of the moist and warm air into the region.

Tibetan High. The Tibetan high intensifies the easterlies to the south of the Himalayas, creates the tropical easterly jet, and provides the upper-air divergence needed for the summer monsoon rains. Normally found at the 200-100 mb level, it is formed in April when a high-pressure cell, formed over the South China Sea, migrates northwestward to the Tibetan Plateau. Figure 2-16 shows the mean positions in July and August. A heat low forms on

the Tibetan Plateau's surface at about the 600-mb level, surrounded by a ring of highs along the plateau's rim. The high is maintained by the plateau's intense heating, latent heat release from the summer monsoon rains, and by dynamic interaction with the subtropical ridge that can cause its position to vary. If the Tibetan high's position shifts east of 90° E, severe drought over East Asia results. The Tibetan high appears to oscillate with a period of 10-16 days.

The northwestward movement of the Tibetan high is one of the requirements for the establishment of the summer monsoon. A 1987 study of this movement shows an example of how the process works. The numbers in Figure 2-17 represent 5-day periods that start 16 April 1987 and end 4 July 1987. The abrupt northward movement during Period 6 (11-15 May) coincided with the onset of the summer monsoon. The establishment of the high over the Tibetan Plateau took place during Period 14 (20-25 June) which corresponded well with the rapid heating of the plateau. During this period, the west-moving high moved with a cell that moved eastward from the Arabian Peninsula. By Period 16, the Tibetan high broke into two cells, one over central China, the other over northern Iran.

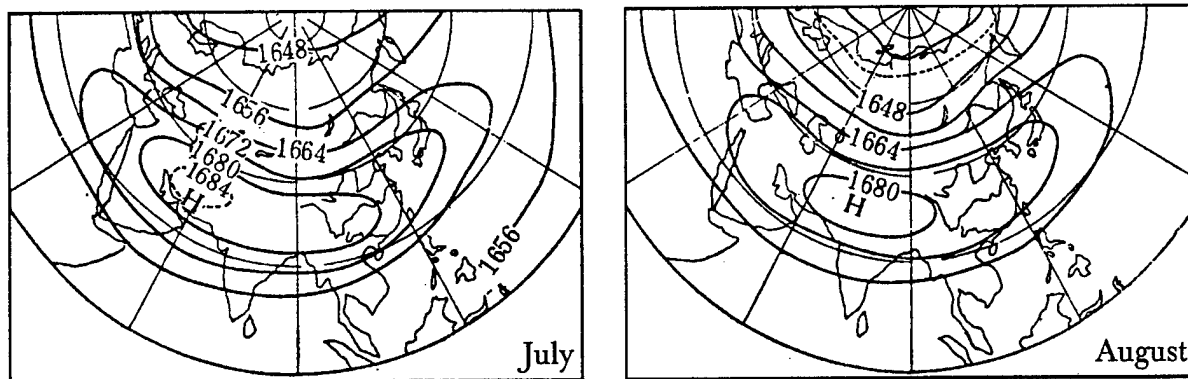


Figure 2-16. Monthly Mean 100-mb Charts in July-August, 1956-1970. The figure shows the mean positions of the Tibetan high.

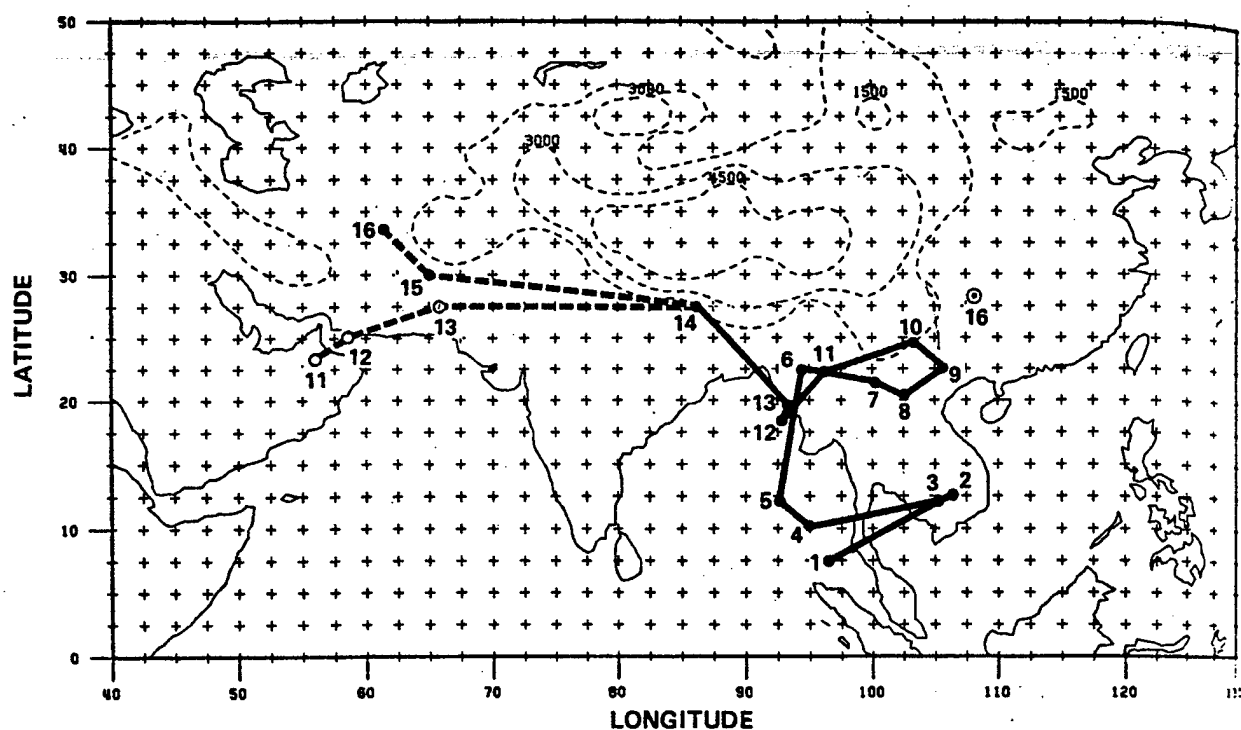


Figure 2-17. Mean Positions of the 200-mb Tibetan Anticyclone between April-July 1979. See text for meaning of numbers.

Mid-Latitude Disturbances

Polar Front. Figures 2-18a and 2-18b show the mean position of the polar front in January and July. The polar front in January coincides with position of the subtropical westerly jet stream that reaches extremely high speeds over eastern Asia in January. It also marks the southern boundary of the winter monsoon. During the summer, the polar front marks the northern boundary of the summer monsoon.

Cyclogenesis/Storm Tracks. The low-pressure systems affecting the region have their origins on the lee side of the Tibetan Plateau over China and Mongolia. After formation, the upper-level westerlies steer the lows eastward along one of four tracks that are named for the low-pressure systems that frequent them (See Figure 2-19).

The lows are classified by their places of origin. Table 2-1 lists these types of lows and their mean seasonal frequency of occurrences, and the corresponding track numbers for Figure 2-19. East China Sea lows do not impact continental East Asia.

The different types of lows vary considerably, both annually and seasonally. The maximum number of lows occur in the spring; the minimum number of lows occur in winter as the strong Asiatic high often suppresses low-pressure system development until the disturbances reach the coast.

Northeast China lows, related to the upper westerly troughs in the polar jet stream, are the most prevalent. They account for 45 percent of the total cases. These lows originate near Lake Baikal, in Mongolia and Nei Mongol or in northeast China, and as they move east-southeast, they usually reach their peak over northeast China. They tend to weaken there and continue their eastward movement to the Sakhalin Island or the Sea of Okhotsk.

Huanghe River lows occur the least. They originate at the great bend, along the lower reaches of the Huanghe River, or over the north China plain. These lows move eastward across Korea and the Sea of Japan to Hokkaido and the Aleutian Islands. A few move through northeast China to Sakhalin Island.

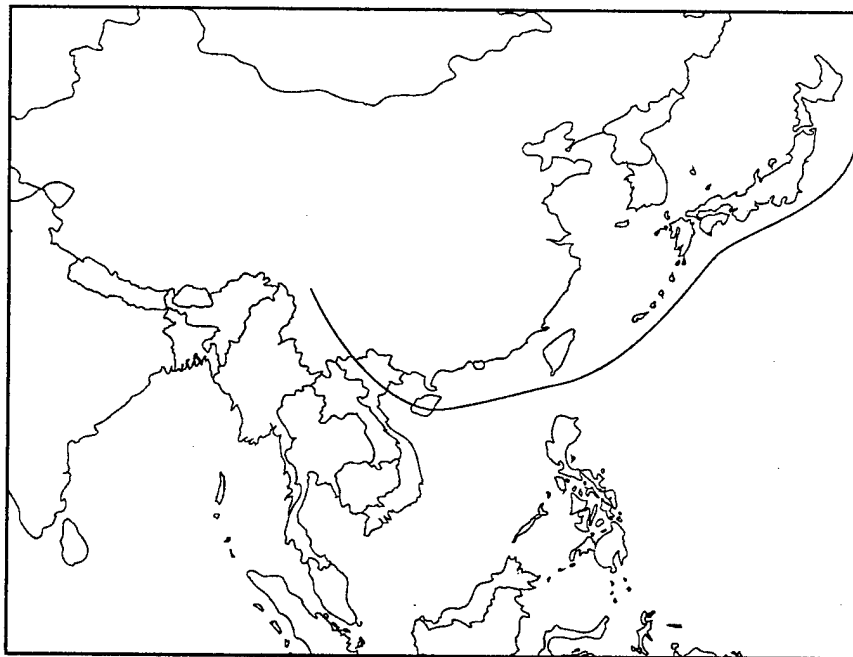


Figure 2-18a. Mean Polar Frontal Positions in January. The polar front in January coincides with position of the subtropical westerly jet stream and marks the southern boundary of the winter monsoon.

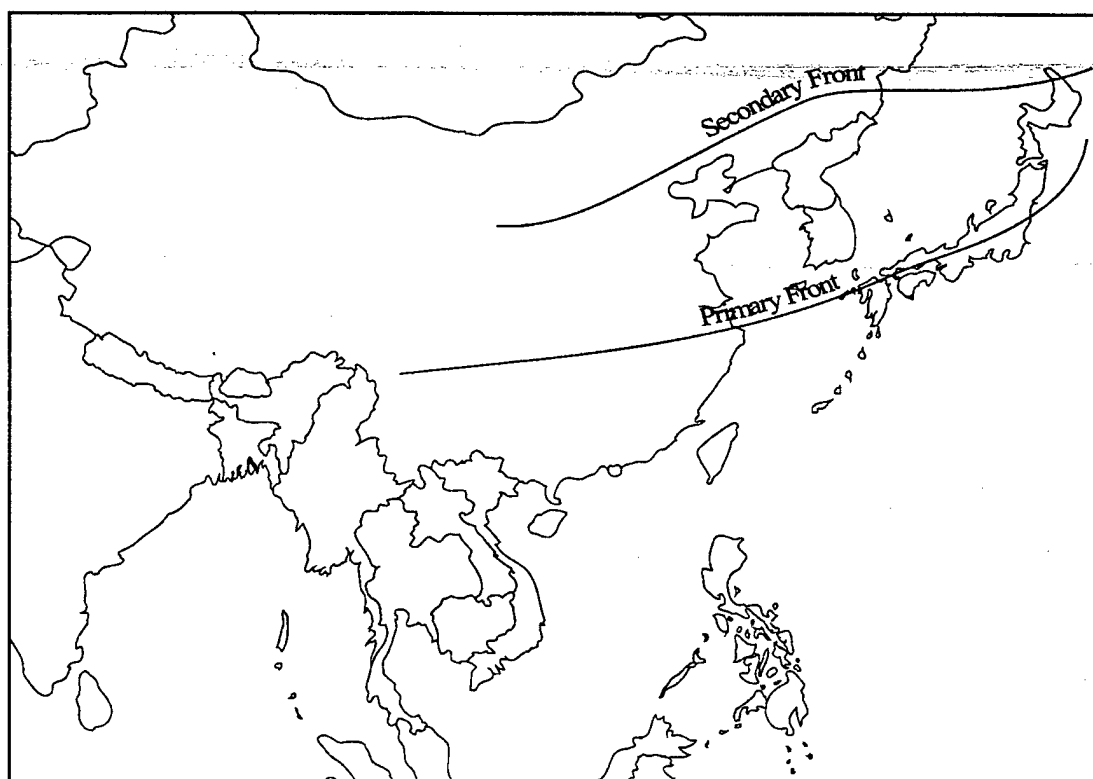


Figure 2-18b. Mean Polar Primary and Secondary Frontal Positions in July. During the summer, the polar front marks the northern boundary of the summer monsoon

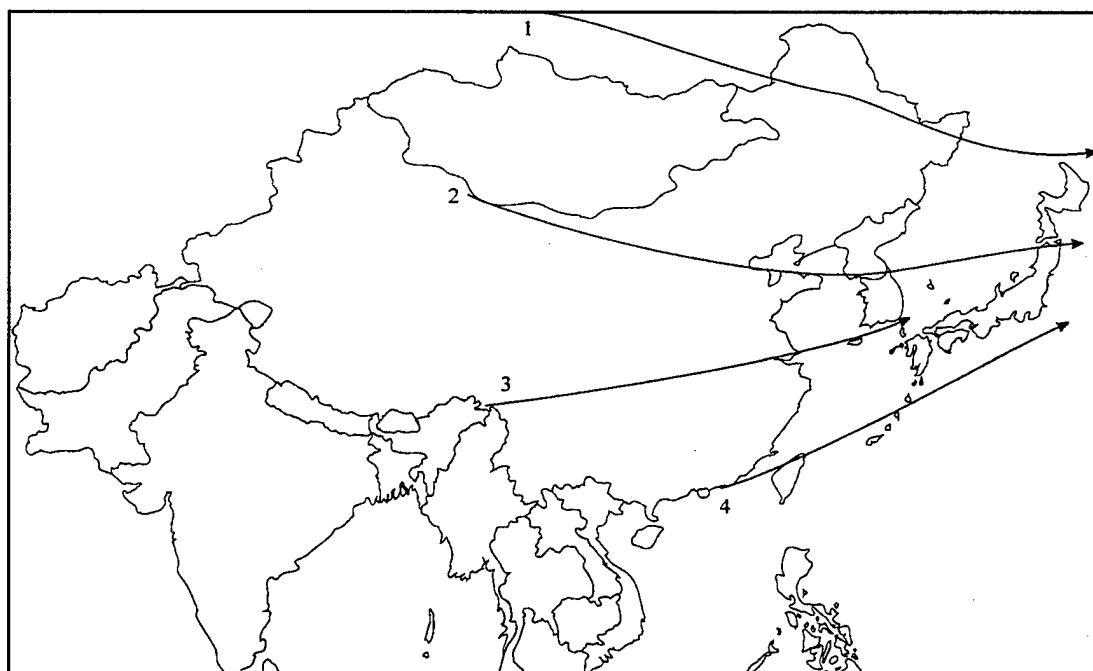


Figure 2-19. Main Storm Tracks Affecting Eastern Asia. The numbers indicate the following positions: (1) Northeast China, (2) Huanghe River, (3) Yangtze-Huaihe, and (4) East China Sea.

Table 2-1. Mean Seasonal Frequencies of Low-Pressure Systems.

Low Type	Spring	Summer	Autumn	Winter	Year
Northeast China	16	10	16	8	50
Huanghe River	1	4	2	2	9
Yangtze-Huaihe	10	8	4	5	27
East China Sea	9	1	6	8	24
Total:	36	23	28	23	110

Yangtze/Huaihe lows originate over the middle and lower reaches of the Yangtze and Huaihe rivers. Most of these lows move eastward to the East China Sea, then east-northeastward over southern Japan to the Aleutian Islands. A few move northeastward across Korea and the Sea of Japan to Hokkaido and the Aleutians. These lows are generally weak in the formative stage with only a frontal wave or one or two closed isobars when over the mainland.

Northeast China and Huanghe River low-pressure systems usually develop along a northern frontal zone while the Yangtze/Huaihe low-pressure system develops along a southern frontal zone. Each system can develop alone or in pairs (see Figure 2-20).

Kunming Quasi-Stationary Frontal Zone. A common feature during the winter in China's eastern Sichuan Province, the Kunming frontal zone develops when cold air from the Asiatic high is blocked by the north slope of the Nanling Mountains, the Yunnan plateau, and the east slope of the Qinghai-Tibet plateau. The front separates the cloudy, rainy, cold, polar air from northeast Asia from the warmer, dry, west-southwesterly air flow from southwest Asia. Winds on the east side of the front are predominately from the northeast at low-levels and veer to west-southwest with altitude. Winds to the west of the front are predominately from the west-southwest at all levels. Figure 2-21 represents a typical location for the Kunming quasi-stationary frontal zone.

SYNOPTIC FEATURES

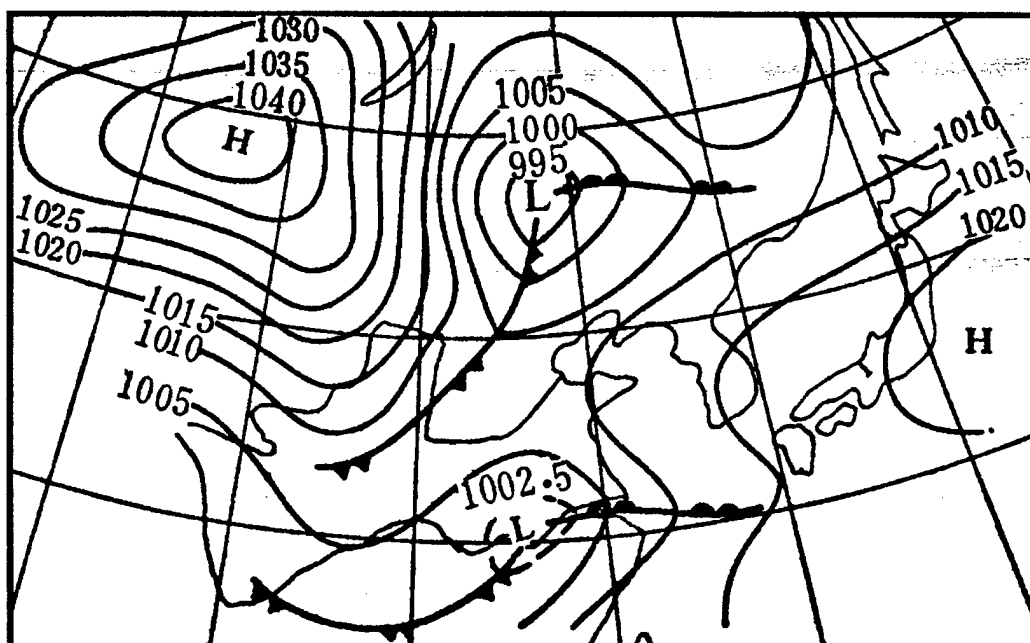


Figure 2-20. Surface Weather Map at 00Z, 5 April 1958. The figure shows development of low-pressure systems along the frontal zones.

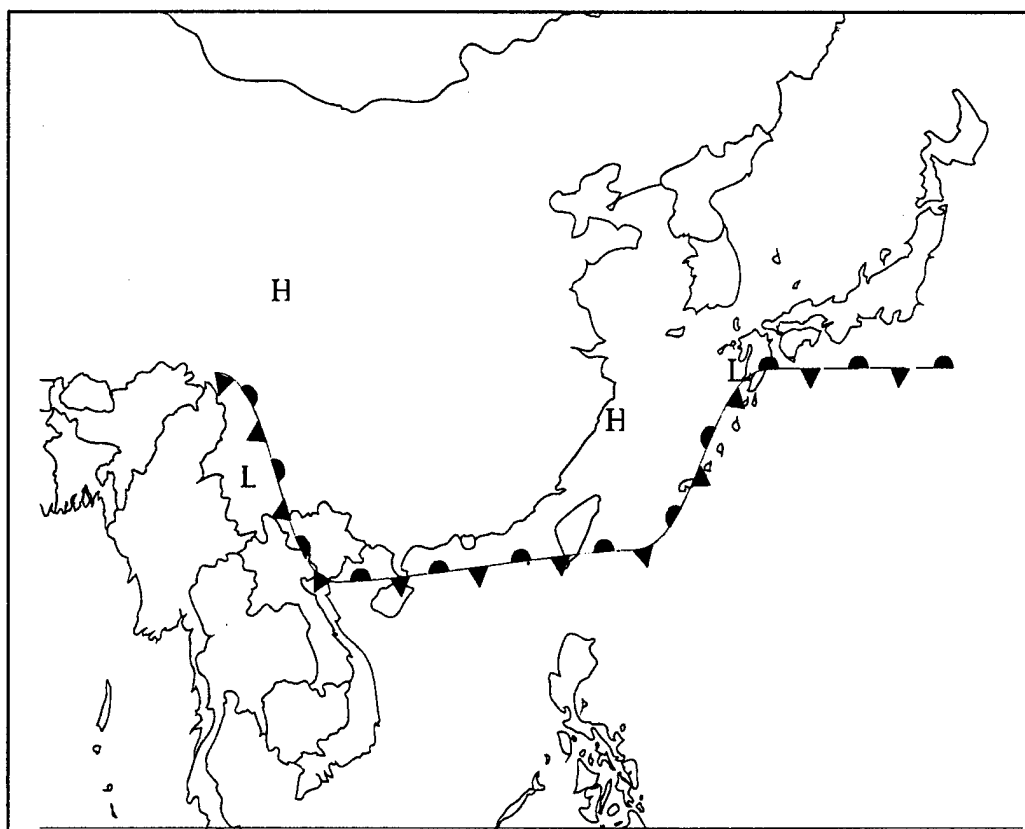


Figure 2-21. Typical Location for the Kunming Quasi-Stationary Frontal Zone. Position based on 12Z, 27 February 1966 surface chart.

Cold Surges. Cold surges are the most prevalent weather processes over East Asia during the winter monsoon. They occur at intervals that range between 4 and 20 days. They are marked by the invasion of extremely dry and cold weather over Mongolia, China, Korea and Japan. The associated weather includes high winds, an abrupt temperature drop, severe frost, freezing rain, heavy snow, and sandstorms.

A close relationship exists between the intensity of the Siberian high and the severity of the cold air surges. One can generally expect a cold air outbreak when the Siberian high builds up to considerable intensity. A study found that cold air outbreaks were likely to occur if the surface pressure of the high exceeded the mean surface

pressure by at least 10 mb. Table 2-2 contains the statistics of the Siberian high's central sea-level pressure for a 22-year period, collected from a region bounded by 45-55° N and 90-105° E. The data shows that cold surges are most common from November to January when the Siberian high is most intense.

Since cold surges occur primarily in the shallow layer below the 700-mb level, their movement is dictated, in part, by the topography of the continent. Despite this, the key to the initiation of the cold air surge is an event that takes place in the upper-level westerlies. It begins with the establishment of a northwesterly flow over the Lake Baikal region above which a short upper-tropospheric trough moves eastward toward the

Table 2-2. The Statistics of Central Sea-Level Pressure of the Siberian High for the Period 1958-1979.

Months	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Mean SLP (mb)	1036	1045	1051	1052	1049	1041	1032
Max SLP (mb)	1057	1075	1087	1085	1081	1074	1076
Mean # Days > 1050 mb	0.8	4.9	9	10.6	7.6	2.6	0.5
Mean # Days > 1060 mb	0	1.4	4.3	4.4	2.7	0.5	0.1
Mean # Days > 1070 mb	0	0.1	1.1	1.1	0.6	<0.1	<0.1
Mean # Cold Surges **	NA	4	4.6	4.3	3.1	1.4	NA

SYNOPTIC FEATURES

long-wave trough along the East Asian coast. As the shortwave trough passes through the long-wave trough position, it intensifies and initiates surface cyclogenesis over the East China Sea. The cyclogenesis, through thermal advection, begins to intensify the Asiatic (Siberian) high. As the surface low intensifies, the pressure gradient between the low and the Siberian high increases and initiates a cold surge. A strong cold front develops ahead of the surge and pushes southward. The front is accompanied by a steep rise of surface pressure, a sharp temperature drop, and a strengthening of the northerly winds. Winds associated with the fronts can reach speeds in excess of 40 knots. As the cold front moves beneath the jet stream, a lot of weather generates along the front. Since the jet seldom shifts southward with the front, the front quickly dries out

when it reaches the subsident region south of the jet.

When the cold surge begins, the high centers tend to move along one of three main tracks (see figure 2-22). These tracks first show a southward movement, then an eastward turn towards Japan. Cold air branches off of the tracks and pushes the cold front southward along the eastern periphery of the Tibetan Plateau. These surges quite often reach the South China Sea. There, they can generate considerable convective activity early in the winter monsoon since the cold air moves out over the still warm ocean. Otherwise, the cold surge enhances the northeast trade winds for 3 to 4 days after the onset of the surge and enhances convection over the west Pacific Ocean.

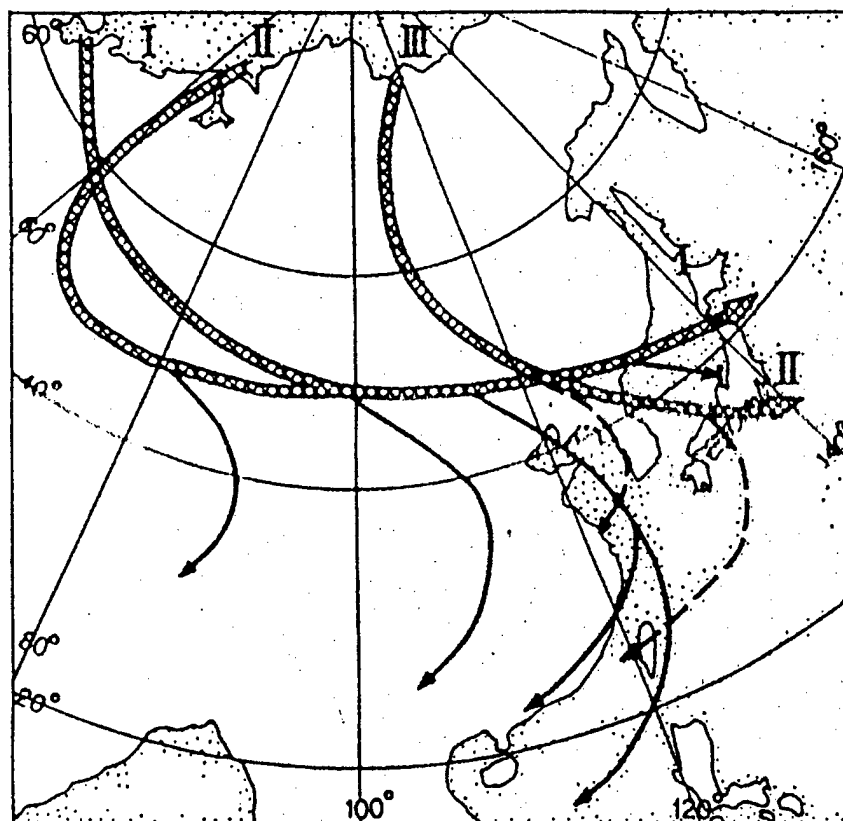


Figure 2-22. Main Tracks of Cold Surges. When the cold surge begins, the high centers tend to move along one of three main tracks.

Southwest China Vortex. The southwest China vortex is a mesoscale, low-level depression that develops in response to distortions imposed upon certain circulation types by the Tibetan Plateau. Table 2-3 is a summary of a 5-year study on the southwest China vortex. It shows that the vortex usually occurs between April and September and is most common in May and June. Forty-one percent of the vortices which develop dissipate in their location of origin. The rest intensify and move out toward the east.

For the southwest China vortex to form in the spring, a trough is needed in the south branch of the 500-mb westerlies over India and the Bay of Bengal. The warm, moist air current passes over the southeastern portion of the Tibetan Plateau and induces a low-level vortex over southwestern China. During the summer, a vortex usually develops over the eastern portion of the Tibetan Plateau when the subtropical high retreats eastward from the plateau. A vortex will also develop over southwestern China when a zonal shear line appears over the Tibetan Plateau or a monsoon depression is over India.

Once a vortex forms over southwestern China, any intensification and movement eastward will

induce extensive heavy rain over eastern and northeastern China. Since around 41 percent of the vortices dissipate where they are formed (see Table 2-4), the forecaster must determine whether the synoptic situation favors eastward movement or dissipation. The synoptic situation favoring movement and intensification follows:

- Strong low-level southwesterly current south of the vortex.
- An appreciable negative height change area around the vortex at least from 850-500 mb.
- Moisture increases near the vortex.

If the vortex is moving out east of a 500-mb trough associated with warm advection and upward motion, the rear of the vortex lies beneath the rear of the trough associated with cold advection and descending motion. For the vortex to dissipate, opposite synoptic conditions are needed.

Once the southwest China vortex begins to move out, it normally moves east on one of three routes. Figure 2-23 shows the expected region of vortex development and the likely routes of movement if the vortex does not dissipate.

Table 2-3. Frequency of Southwest China Vortex Occurrence and Tracks in 1970-1974.

Month	Apr	May	Jun	Jul	Aug	Sep	Total
Mean #:	8.8	11.2	10	7	3.2	8.3	48.5
Dissipated:	36%	25%	44%	49%	50%	55%	41%
Moved E:	38%	60%	36%	23%	6%	30%	38%
Moved NE:	16%	13%	12%	11%	31%	15%	14%
Moved SE:	9%	2%	8%	17%	13%	0%	7%

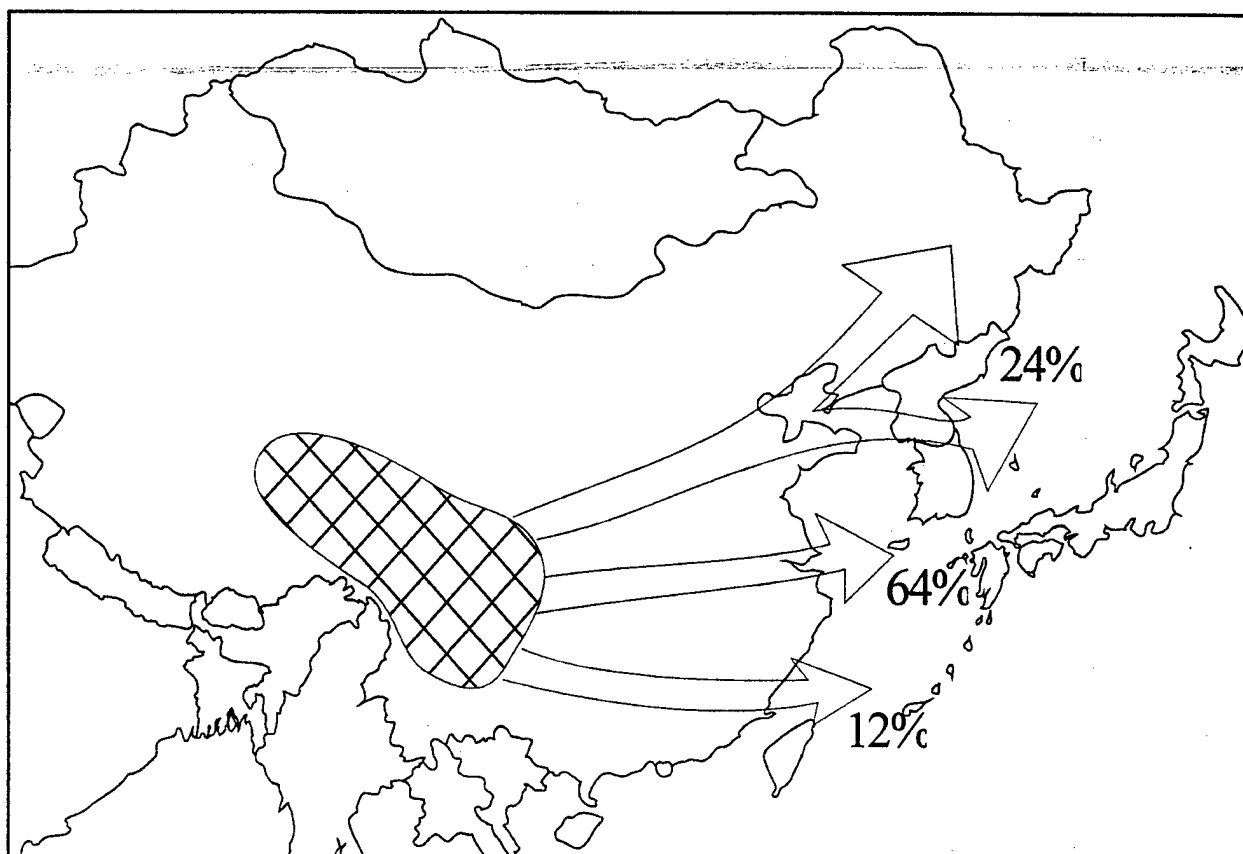


Figure 2-23. Area of Southwest China Vortex Development and Primary Tracks in 1971-1974. This figure shows the expected region of vortex development and the likely routes of movement if the vortex does not dissipate.

Duststorms/Sandstorms. Given the right conditions, duststorms are dominant features in and near the deserts of the region. Duststorms carry suspended particles over long distances and often reduce visibility to less than 10 meters. Season of occurrence, wind direction, amount of particulate matter, and duration all vary by locality. Large-scale duststorms often persist for 1 or 2 days before a frontal passage or with a synoptic-scale squall line. Mesoscale squall lines may reduce visibility to less than 1,000 meters for several minutes to an hour. Sandstorms differ from duststorms only in the size of the suspended particles. Sand, being heavier, is seldom raised to more than 3-6 feet (1-2 meters) above the ground; the particles settle quickly.

Winds of 15-20 knots are sufficient to lift dust and sand. The mean threshold value is 17 knots, but speeds as low as 10-12 knots can produce duststorms. A pressure gradient of 6 mb per 10 degrees of latitude produces widespread duststorms 50 percent of the time. A 4 mb per 10 degrees of latitude surface pressure gradient is necessary to generate dust-laden surface winds.

Dust devils resemble miniature tornadoes, but their wind speeds are generally only between 10 and 25 knots. They can get strong enough to flatten huts. They form in clear skies and are set off by intense, summer daytime heating and local turbulence. Diameters range from 10 to 295 feet (3 to

90 meters) but average around 69 feet (6 meters). Most reach 246 feet (75 meters) high, but dust has been observed at 2,950 feet (900 meters). Dust devils move at about 10 knots and last for 1 to 5 minutes. Visibility is near zero in the vortex. The origin and nature of duststorms depend upon general synoptic conditions, local surface conditions, seasonal considerations, and diurnal considerations.

General Synoptic Conditions.

- Active cold fronts. Sandstorms/duststorms can develop with frontal passages. Strong fronts increase the size of the area affected considerably and can produce a "wall of sand."
- Convective activity. Convective downdrafts commonly reach speeds needed to produce duststorms and sandstorms. Visibility can be greatly reduced within minutes.

Local Surface Conditions. Soil type and condition control the amount of particulate matter that can be raised into the atmosphere. Dry sand or silt, for example, is easily lifted by 10-15 knot winds. Haze is a persistent feature of the sandy deserts. Fine dust, salt, or silt can be suspended for weeks and travel hundreds, even thousands, of kilometers from the source. Vehicles crossing the sand break through the crust easily; even light winds can raise dust.

Seasonal Considerations.

- Winter. Large areas of dust/haze develop when a cold air surge from the Asiatic (Siberian) high moves into the region. Most duststorms develop along frontal boundaries. Synoptic-scale winds of only 10 to 15 knots can lower visibility to less than 3 miles

(4,800) meters over large areas for up to 12 hours.

- Summer. Convection produces most duststorms, but late-spring frontal systems also produce them. Duststorms are more frequent in summer than in the winter. Local visibility is below 5,000 meters in areas where the soil is dry.

Diurnal Considerations.

- Daytime. The lowest visibility occurs shortly after the inversion breaks and turbulent surface mixing raises dust. Distant tree tops can be visible at this time, but their bases are obscured by the dust/haze. Daytime heating produces turbulent mixing in the lowest layers. Hot, dry winds transport dust aloft to the base of the large-scale subsidence inversion. Persistent dryness allows dust to reach 9,800 feet (3,000 meters) MSL where it can remain suspended for days or weeks.
- Nighttime. Cooler surface temperatures create stable conditions in the surface layer. Turbulent mixing is minimized; visibility improves during the night and is best between 2000 and 0600L as the temperature inversion produces light surface winds. Dust settles beneath the inversion layer throughout the night; visibility improves to 6,000-10,000 km.

Sandstorms are quite prevalent over the Asian mainland during the year. Figure 2-24 shows the distribution of sandstorm activity over China. The highest incidence of sandstorms is in the northwest deserts. The number of sandstorms decreases towards the southeast. Spring or early summer has the highest incidents of sandstorm. In continental East Asia, the incidence of sandstorm activity is highest in May and June.

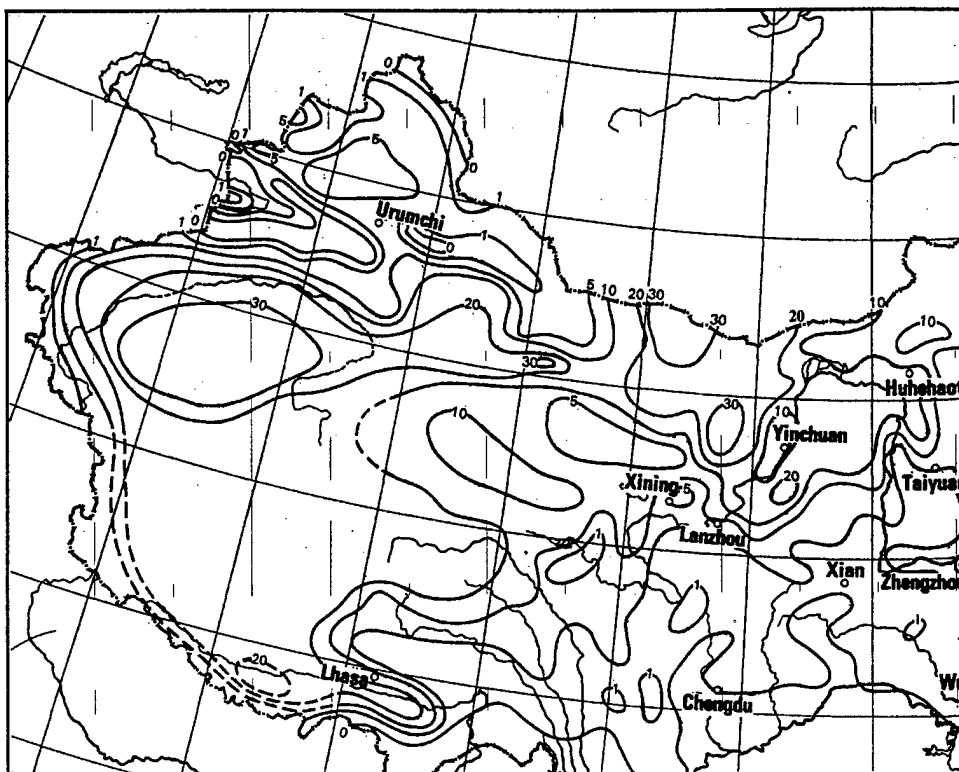


Figure 2-24. Mean Annual Number of Days with Sandstorms. The figure shows the distribution of sandstorms over continental East Asia. Dashed lines indicate extrapolated data.

Diurnal Circulations.

Land/Lake Breezes. Several localized variations of the land/sea breeze circulation are caused by differential heating over large lakes. This circulation occurs in the absence of strong synoptic flow; it has a vertical depth ranging from 650 to 1,650 feet (200 to 500 meters) AGL. Figure 2-25 shows a land/lake circulation and cloud pattern associated with no synoptic flow. In late afternoon, a cloud-free lake is surrounded by a ring of convection some 12 to 25 miles (20 to 40 km) inland from shore. By early morning, the flow reverses and localized convergence occurs over open water.

Mountain/Valley and Slope Winds. These winds develop under fair skies with light and variable synoptic flow. Mountain/valley winds, like land/sea breezes, dominate the weather in the absence of defined synoptic flow. There are two types of

terrain-induced winds: valley winds and slope winds. They are shown in Figure 2-26. Valley winds tend to be stronger than slope winds and can override their influence.

Valley winds are produced in response to a pressure gradient between a mountain valley and a plain outside the valley. Air within the valley heats and cools faster than air over the plain. Daytime up-valley winds are strongest, averaging 10-15 knots between 650 and 1,800 feet (200 and 400 meters) AGL. Nighttime down-valley winds average only 3-7 knots at the same level. Peak winds occur at the valley exit. Deep valleys develop more nocturnal cloud cover than shallow valleys because nocturnal airflow convergence is stronger. The mesoscale mountain-valley circulation, which has a maximum vertical extent of 6,500 feet (2,000 meters), is determined by valley depth and width,

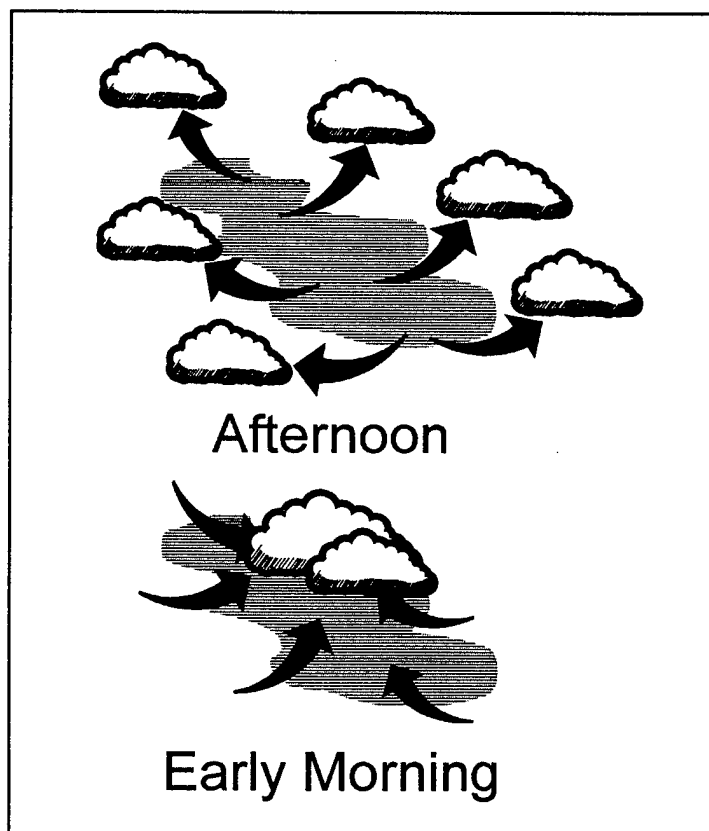


Figure 2-25. Idealized Land/Lake Breezes with Cloud Pattern. The figure shows a land/lake circulation and cloud pattern with no synoptic flow.

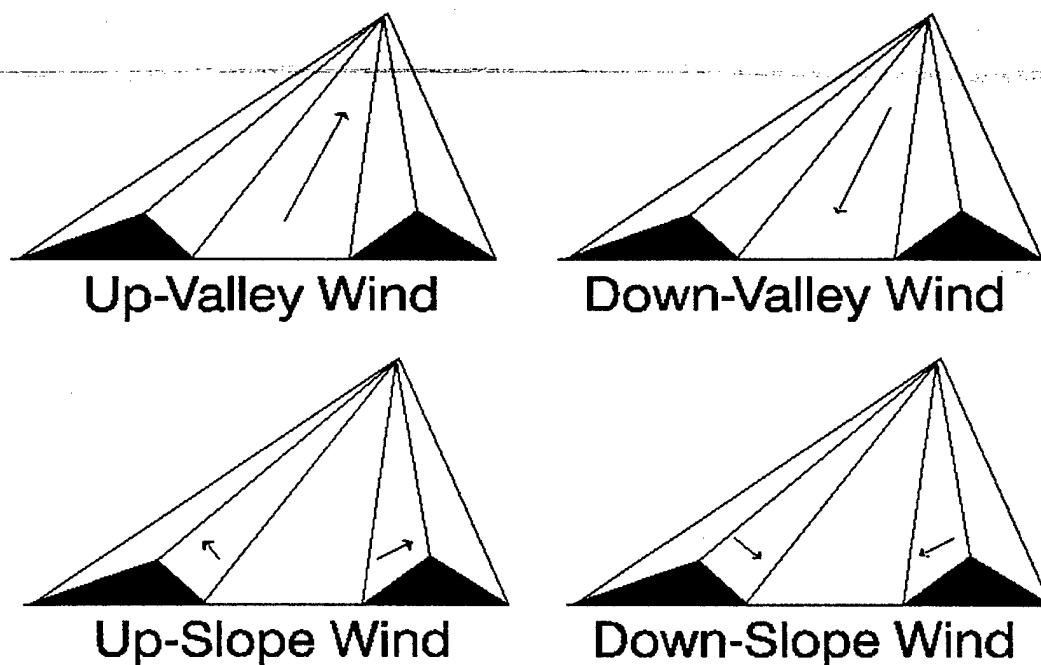


Figure 2-26. Mountain-Valley and Slope Winds. The figure shows the two types of terrain-induced wind.

prevailing wind strength in the mid-troposphere (stronger winds producing a more shallow circulation), and the breadth of microscale slope winds. The return flow aloft is much weaker and broader since it isn't confined to a narrow valley.

Slope winds develop along the surface boundary layer 0 to 500 feet (0 to 150 meters AGL) of mountains and large hills. Mean daytime upslope wind speeds are 6-8 knots; mean nighttime downslope wind speeds are 4-6 knots. Steep slopes can produce higher speeds, but these speeds are found at elevations no higher than 130 feet (40 meters) AGL. Downslope winds are strongest during the season with the greatest cooling while upslope winds are strongest during the season of greatest heating. Upslope winds are strongest on the slope facing the sun. Winds from a larger mountain can disrupt the winds of a smaller mountain. In some locations, cold air can be dammed up on a plateau

or in a narrow valley. When sufficient air accumulates, it can spill over in an "air avalanche" of strong winds.

Figure 2-27 shows the life cycle of a typical mountain-valley and slope wind circulation. Mountain inversions develop when cold air builds up along wide valley floors. Cold air descends from slopes above the valley at 8-12 knots, but loses momentum when it spreads out over the valley floor. Wind speeds average only 2-4 knots by the time the down slope flow from both slopes converge. The cold air replaces warm, moist valley air at the surface and produces a thin smoke and fog layer near the base of the inversion. First light initiates upslope winds by warming the cold air trapped on the valley floor. Warming of the entire boundary layer begins near the 500-foot (150-meter) level AGL.

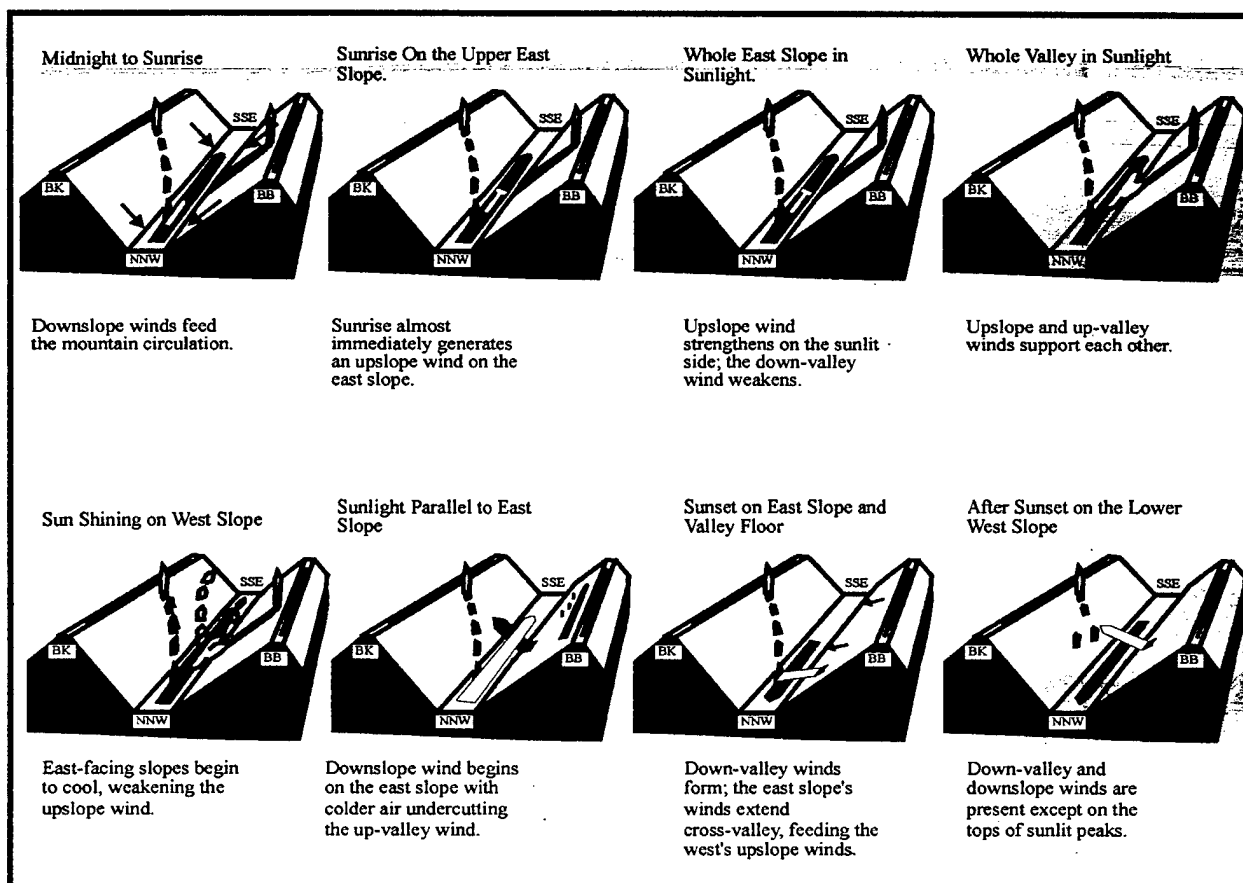


Figure 2-27. Diurnal Variation of Slope and Valley Winds. Both valley and slope winds are shown in relation to two ridges (BK and BB) oriented north-northwest to south-southeast. The dark arrows show the flow near the ground; the light arrows show movement of the air above the ground.

Local Wind Systems

Mountain Waves. These waves develop when air at lower levels is forced up over the windward side of the ridge. Criteria for mountain wave formation include sustained winds of 15-25 knots, winds that increase with height, and flow oriented within 30 degrees of perpendicular to the ridge.

Wavelength amplitude is dependent on wind speed and lapse rate above the ridge. Light winds follow the contour of the ridge with little displacement above and rapid damping beyond. Stronger winds displace air above the stable inversion layer; upward displacement of air can reach the tropopause. Downstream, the wave propagates for an average distance of 50 times the ridge height. Rotor clouds form when there is a core of strong wind moving over the ridge, but the elevation of the core does not exceed 1.5 times the ridge height. Rotor clouds produce the strongest turbulence. The clouds may not always be visible in dry regions. Figure 2-28 is an illustration of a fully developed lee-side wave.

Föhn's. Hot, dry winds produced when air is forced over mountains are called föhns. They become hot and dry by adiabatic warming as they descend the leeward slope. Climatic parameters for these winds are defined as a daily maximum temperature 30° C, a relative humidity of 30 percent, and a wind speed greater than 6 knots. Favorite locations for the formation of föhns are along the northeast coast of Korea during the winter, northern and northeastern China from mid-May to late June, and downwind of mountain ranges when conditions are favorable.

Gap Winds. Gap, "jet-effect," or venturi winds occur on the downward sides of narrow mountain passes under strong gradient conditions induced by the funneling of the wind. These winds are almost always "supergradient" with speeds as much as 35 to 45 knots higher than otherwise expected. The most common locations are mountain passes along the Sino-Russian border where winds speeds exceed 97 knots with maximum gusts of 136 knots.

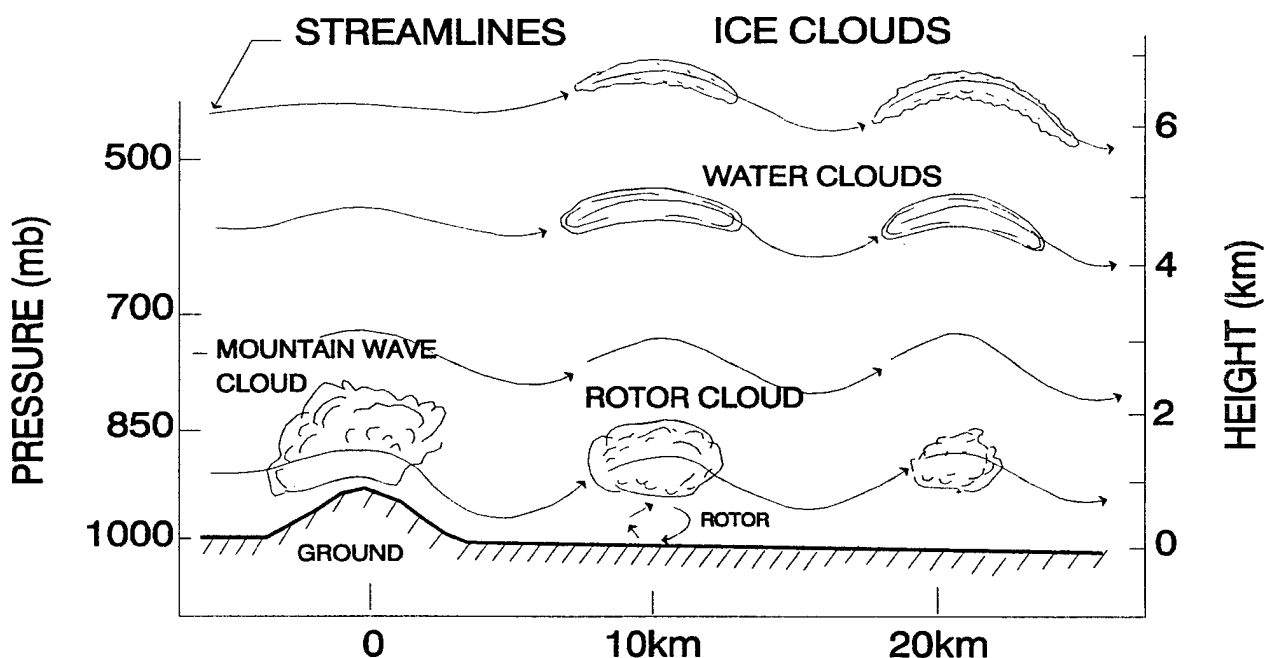


Figure 2-28. Fully-Developed Lee Wave System . The figure depicts the features associated with mountain waves including the hazardous rotor cloud located downstream from the wave.

Effects of the Tibetan Plateau. The Tibetan Plateau is the tallest highland in the world; it is known as the "Roof of the World." It covers a geographical region from 30° to 38° N, 70° to 100° E, with an average elevation greater than 14,763 feet (4,500 meters). The plateau is home to many mountains whose peaks exceed 19,685 feet (6,000 meters) including the world's tallest, Mt. Everest, at 29,028 feet (8,848 meters). The presence of such a huge land feature in the western portion of the region obviously affects the weather patterns for the region. In this section, discussion of the Tibetan Plateau will be limited to the dominant jet streams of the region and the Asiatic (or Siberian/Mongolia) high.

Jet Streams. During fall, winter, and spring, the Tibetan Plateau acts as a high-level radiation heat source. The associated rising surface pressures diminish the south-to-north temperature gradient and reduce the strength of the subtropical jet to the south of the plateau. Air subsides just to the east of the plateau and is further warmed by adiabatic heating. This air flows alongside very cold air that moves around the northern edge of the plateau over central China and induces an extremely large temperature gradient. This temperature gradient produces an extremely strong jet stream over East Asia, especially during winter, with wind speeds as high as 240 knots.

During the summer, the central and southeastern portions of the plateau continue to act as a heat source. Condensation from the Himalayas powerfully aids the effects of radiation. The subtropical ridge aloft lies over the southern portion of the plateau, and any adiabatic heating produced by mechanical subsidence is negligible. As a result, the surface pressure is higher at Lhasa, in southern Tibet, than in areas to the east or west. Instead of weakening the south-to-north temperature gradient as seen in the winter, the heating increases the north-to-south temperature gradient of the summer monsoon and produces a speed maximum in the upper-tropospheric easterlies south of India. These winds possess

some jet stream characteristics and are collectively known as the tropical easterly jet.

Without the Tibetan Plateau, it is very likely that the jet streams would not be as strong as they are because the strong temperature gradients, which the plateau induces, would not exist. It is also possible that the tropical easterly jet would not exist. This would remove one of the most important circulation features of the summer monsoon and would change precipitation patterns in the East Asian region.

Asiatic (Siberian or Mongolia) High. As discussed earlier, intense anticyclogenesis, supported by radiational cooling, leads to the development of the Asiatic high in the Lake Baikal region of Siberia. Cold surges break away from the high to reinforce the northeast monsoon and sweep out to affect southern China, China seas, Korea, and Japan. During numerical modeling of the global atmospheric circulation, researchers found that the Tibetan Plateau was needed to reproduce the Asiatic high. When the high terrain of the plateau and the Himalayan Mountains were removed from the model, the Asiatic high did not appear on the surface map. Analysis of the results of this modeling effort indicated that without the plateau and the mountains, an active baroclinic zone would exist between the radiatively cooling air over wintertime Siberia and the convectively heated air over the Indian Ocean region. Heat would be transported northward by baroclinic wave cyclones to counteract the radiative cooling. Simply put, without the "orographic dam" (the Tibetan Plateau and the Himalayan Mountains) to significantly diminish the northward advection of heat during the winter, the Asiatic high would not exist. If it did exist, it would not be as strong, and the winters over East Asia would be warmer.

The impact of the Tibetan Plateau on the climate of East Asia was demonstrated by the examples given above. Only by understanding how the plateau influences the development of these important climatic features will one truly appreciate its effect.

MESOSCALE AND LOCAL EFFECTS

Wet Bulb Globe Temperature (WBGT) Heat Stress Index. The WBGT heat stress index provides values that can be used to calculate the effects of heat stress on individuals. WBGT is computed using the formula:

$$\text{WBGT} = 0.7\text{WB} + 0.2\text{BG} + 0.1\text{DB},$$

where: WB = wet-bulb temperature
BG = Vernon black-globe temperature
DB = dry-bulb temperature

A complete description of the WBGT heat stress index and the apparatus used to derive it is given in Appendix A of TB MED 507, *Prevention, Treatment and Control of Heat Injury*, July 1980, published by the Army, Navy and Air Force. The physical activity guidelines shown in Table 2-4 are based on those used by the three services.

Figure 2-29 gives average maximum WBGTs for the months of April through October. For more information, see USAFETAC/TN-90/005, *Wet Bulb Globe Temperature, A Global Climatology*.

Table 2-4. WBGT Heat Stress Index Activity Guidelines. Note that the wear of body armor or NBC gear adds 11 Fahrenheit (6 Celsius) degrees to the WBGT, and activity should be adjusted accordingly. The work/rest interval is given in minutes.

WBGT (° C)	Water Requirement	Work/rest Interval	Activity Restrictions
32-up	2 quarts/hour	20/40	Suspend all strenuous exercise.
31-32	1.5-2 quarts/hour	30/30	No heavy exercise for troops with less than 12 weeks hot weather training.
29-31	1-1.5 quarts/hour	45/15	No heavy exercise for unacclimated troops, no classes in sun, continuous moderate training 3rd week.
28-29	.5-1 quart/hour	50/10	Use discretion in planning heavy exercise for unacclimated personnel.
24-28	.5 quart/hour	50/10	Caution: Extremely intense exertion may cause heat injury.

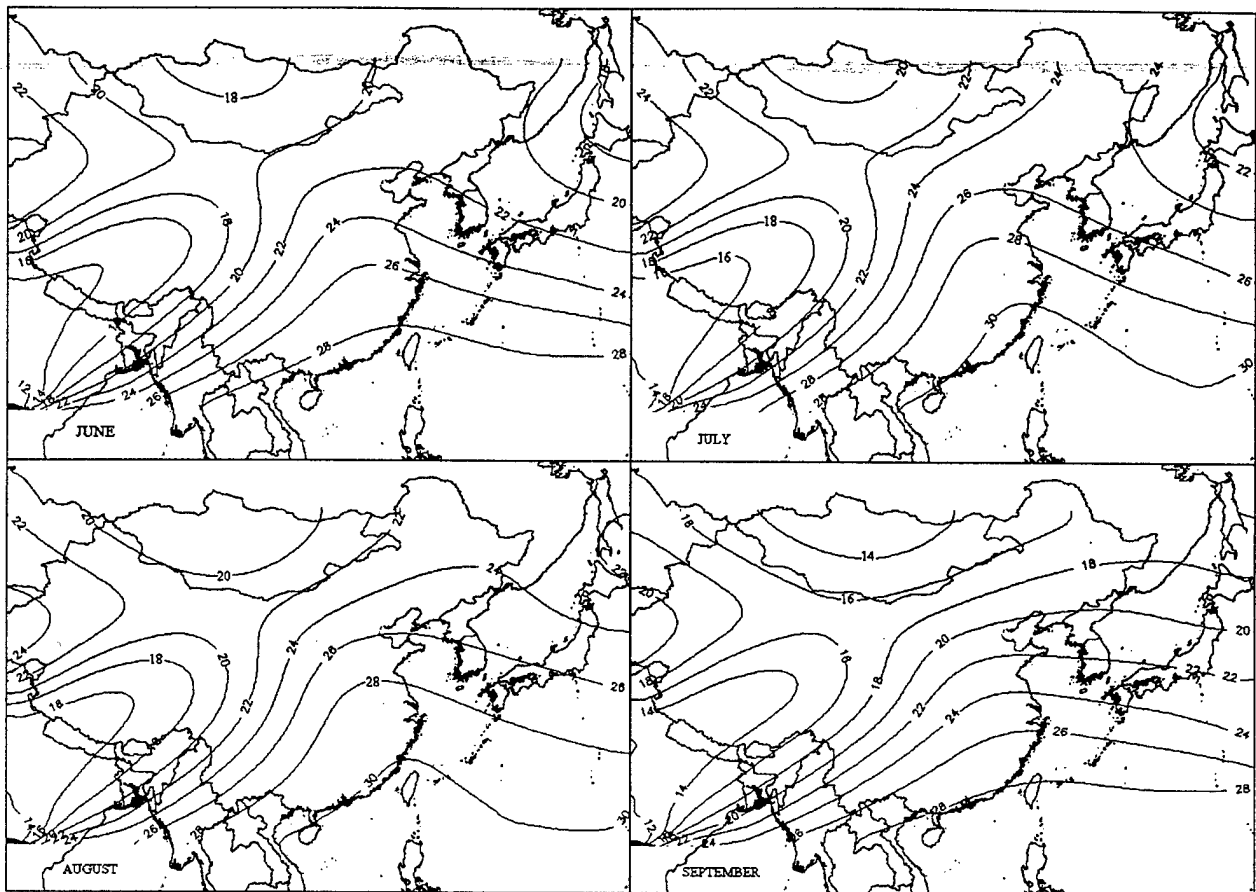
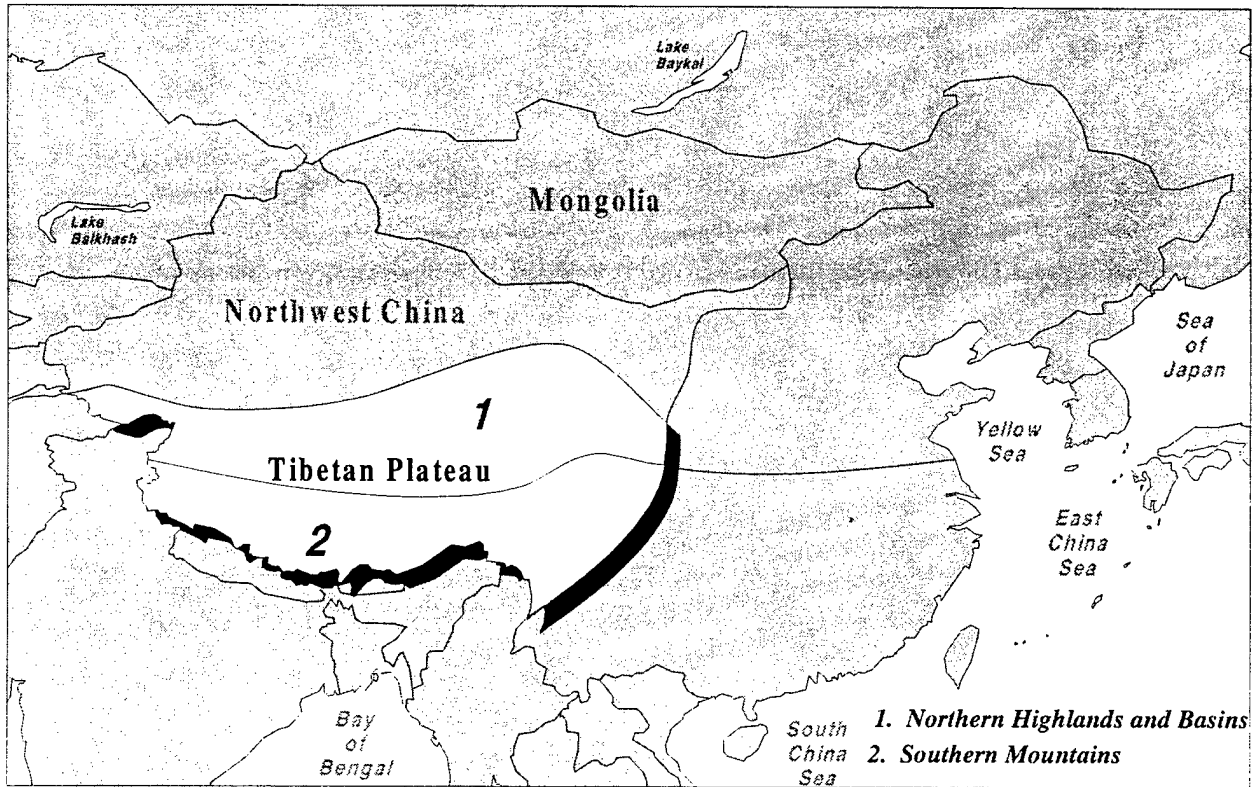


Figure 2-29. Mean Maximum WBGT for Months of June through September. The figure shows the mean maximum WBGT for the months that require activity restrictions to minimize heat injury.

Chapter 3

THE TIBETAN PLATEAU

This chapter describes geography, major climatic controls, special climatic features, and general weather (by season) of the Tibetan Plateau. The plateau, which is an extremely complex climatic zone, includes the area from the northern sections of the Himalaya Mountains to the southern portion of the Kunlun Mountains in western China. For the purposes of this study, the zone has been further subdivided into two smaller "zones of climatic commonality," called the Northern Highlands and Basins, and the Southern Mountains.



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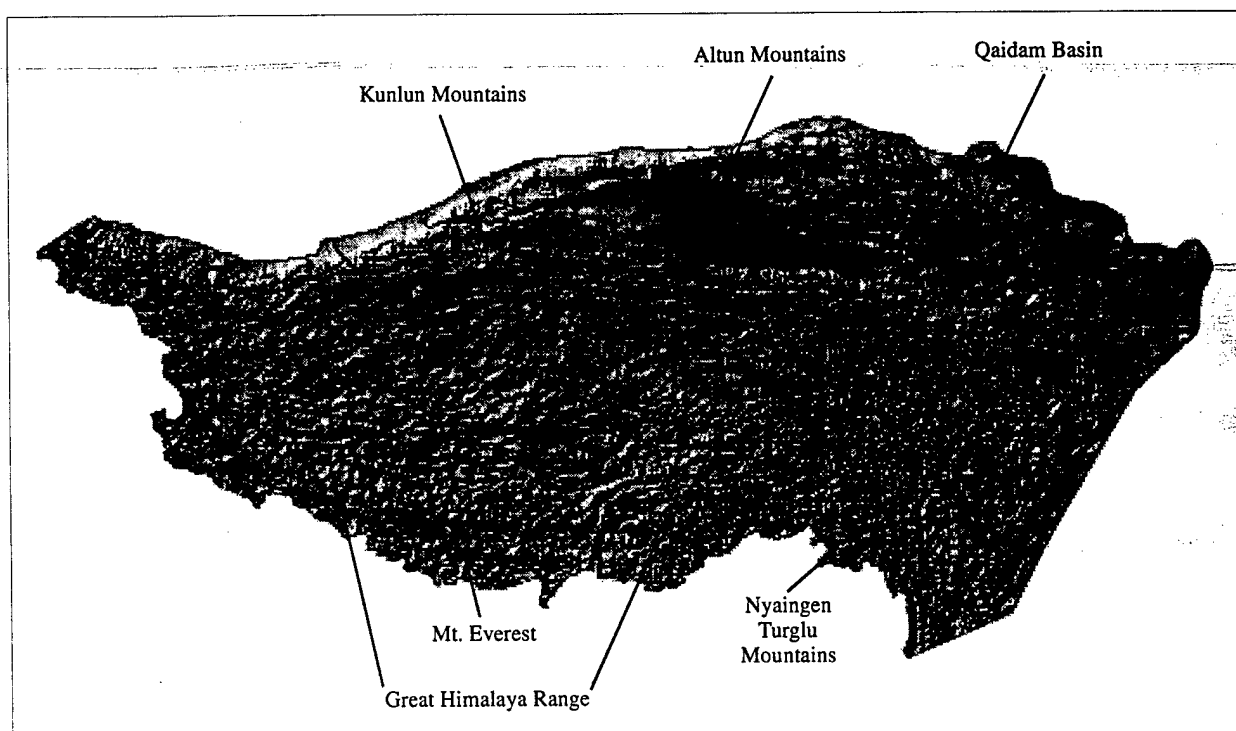


Figure 3-1. Topography. This map shows major terrain features for the area of interest.

Boundaries. The plateau includes the provinces of Xizang, Qinghai, western Sichuan, and extreme northern Yunnan. The northern boundary of the Tibetan Plateau begins along the northern border of the Xizang and Gansu provinces and includes the Kunlun and Altun mountain ranges to the 5,900-foot (1,800-meter) elevation contour along the northern slopes. The eastern boundary follows the western border of the province of Gansu to the south and runs across the western third of Sichuan along the 103° E parallel and into extreme northern Yunnan. The southern boundary follows the northern slopes of the Himalayan Mountains and borders the countries of Myanmar, India, Bhutan, and Nepal. The western boundary is bounded by the disputed territories of Kashmir and Jammu.

Terrain. The Tibetan Plateau is a vast, high plateau surrounded by enormous mountain ranges. The plateau lies between the Kunlun Mountains to the north and the Himalayas to the south and is a region of tangled mountains that rise between 13,100-

16,400 feet (4,000 to 5,000 meters). The relatively level northern part of the plateau is called the northern plain, and it extends more than 800 miles (1,300 km) from west to east at an elevation of 15,100 feet (4,600 meters). Plains occupy a large part of the surface of the plateau in respect to area. However, the mountains constitute such an important element in the relief that special attention is given to them.

The western and southern border of the plateau of Tibet is formed by the Himalaya Mountains. Several peaks reach above 6,100 meters (20,000 feet), including Mount Everest, the world's highest peak at 29,028 feet (8,848 meters), on the Nepal border.

The Himalayan Mountains are actually composed of three different mountain ranges: Siwalik Range, Mahabharat Range, and the Great Himalayas. The Great Himalayan Range's northern periphery is the only range that is part of the plateau. The Himalaya Mountain system is 1,500 miles (2,400 km) long

and between 124 and 217 miles (200 and 350 km) wide. The Great Himalayan Range is completely covered with permanent ice and snow in the higher elevations. Between the several mountain chains of the Himalayas are intermountain lowlands, some of which are impassable due to high cliffs and raging rivers. The northern slopes of the Himalayas are more gentle than those facing toward India and are less dissected by valleys and river courses. The surface of the northern slopes of the Himalayas in many places consists of rocky, rolling inclines with alternating steppes and saline deserts.

The Gandise Mountains (Trans-Himalayan) are separated from the Himalayas by the Brahmaputra River, which flows across southern Tibet and then cuts south through the mountains to India. These mountains rise to 18,000-19,700 feet (5,500 to 6,000 meters). Many of these mountains have gentle slopes with the highest strongly dissected and crowned with eternal snows or glaciers.

The Kunlun Mountains are the lofty uplifted northern edge of the Tibetan Plateau. This is the largest mountain system of Asia. It extends approximately 1,600 miles (2,500 km) between 77° and 105° E. The width along the northern edge of the plateau varies from 90 miles (150 km) in the west to 190 miles (300 km) in the east. The average elevation of its crest is 19,700 feet (6,000 meters). Individual massifs soar to 23,000 feet (7,000 meters). For example, at 25,348 feet (7,726 meters), Muztag Massif is the highest peak in the Kunlun Mountains. Approximately eight ranges are in the southeastern portions of the plateau that run from northwest to southeast. These mountains aid in channeling moisture and precipitation into the plateau. This moderates temperatures during the summer monsoon.

Rivers and Drainage Systems. Tibet is a primary source of water for central Asia. The rivers and lakes receive maximum water during July and August when the monsoonal rains occur and maximum temperatures are observed. The high temperatures cause strong snow and ice melting in the mountains. Both the north and south regions have two high-water stages. The first occurs in early summer as a result of melting snow from the

mountains and hollows. The second high-water period coincides with the summer monsoonal rains. There is also a diurnal characteristic to the high-water stages. During maximum heating the thawing of streams and rivers increases, and the corresponding water level increases. This is when the rivers are the deepest and crossing them is most dangerous due to the swift currents and turbulence. When the temperature drops at night, the water level also drops. The water level is normally at its lowest by morning. The rapid rise and fall of water levels is more noticeable in northern Tibet where there is a lack of forests and grass cover. In southern Tibet, the rise in water level is not as noticeable because of the large river basins. With rare exceptions, the rivers of northern Tibet freeze to the bottom in winter. The spring and ground water that enter rivers come out on the surface of the ice and refreeze into broad layers of ice.

The longest river on the Tibetan Plateau begins in the west as the Marquan River. It becomes the Brahmaputra River in south central Xizang. The Indus River (Shih-ch'uan Ho) has its source in southwestern Tibet near the Kailas Mountain range; it flows northwest across Kashmir to Pakistan. Three other rivers also begin in the west. The Xiangquen He River flows west into India. In east Tibet, the Nu Jiang River begins its trek across Tibet and curves southward into Yunnan Province. The Lancang Jiang (Mekong) River begins in the Qinghai Province as two rivers; the Zi Ou and the Za Ou that flow southward through eastern Tibet. The Tuoto He (Yangtze) River also begins in the eastern Qinghai Province and flows southward into the Tongtian He. The Huang Ho (yellow river) begins in the eastern part of Qinghai Province and flows eastward into northern Sichuan.

One of the peculiarities of the Tibetan Plateau is the numerous scattered lakes many of which are mineralized and high in saline deposits. A pattern can be observed to the distribution of lakes. Their number and size increases from north to south, and this is especially true for the eastern part of Tibet. The lakes are arranged either in broad, but shallow basins on the flat plains or in depressions surrounded on all sides by mountains. Some of the lakes exist

TIBETAN PLATEAU GEOGRAPHY

only in the summer when depressions are filled with rain or snow melt. The lakes dry up in the fall and become salt marshes.

Tibetan lakes, much like rivers, receive their summer rain from the southwest monsoon or from melting snows and glaciers. The depth of lakes varies seasonally. In summer, the water level is sharply higher due to the added water. In fall, when the rains and thawing ceases, the water level drops sharply. Some strongly mineralized lakes become freshwater lakes or only weakly saline during summer. In fall, because the freshwater supply is cut and strong evaporation occurs, they again become saline.

Two of the largest lakes are located northwest of Lhasa. Nam Lake covers an area of 1,300 square miles (2,200 sq km), and Siling Lake covers an area of 1,000 square miles (1,700 sq km). On the Tibetan highland, there are overflows of thermal springs or geysers. Many of these occur from the north of the Brahmaputra River to about 34° N, between 88° and 92° E. These geysers can sometimes eject a stream of boiling water as high as 32 to 49 feet (10 to 15 meters). Many geysers are situated along the banks of some of the major lakes. Despite the high internal temperature, many springs and geysers freeze during the severe Tibetan winters although they don't always cease their activity. Temperatures ranging from -22° to -40°F (-30° to -40°C) suffice to form a cowl of ice over the geyser. This cowl allows the geyser to continue to spout hot steam.

Vegetation. The plateau has grasslands, which natives use as pastures. Barley is grown on the plateau as well. Forests cloak plateau valley slopes, especially in the south. The most extensive farming areas in Tibet are the fertile plains around the Brahmaputra River and its tributaries.

Soils are sediments deposited by rivers and runoff, and they are often composed of sand that is blown by the wind from a layer above the coarse gravels that dominate the plateau. Color of soils vary from light brown to gray according to the humus content, which is generally poor. Windswept northern Tibet

is devoid of trees and larger forms of vegetation. Its arid climate supports little except grasses.

The varied plant life of Tibet is found in the river valleys and in the lower, wetter regions of the south and southeast. Plants include willows, poplars, several types of conifers, teaks, rhododendrons, oaks, birches, elms, brimpos, sugarcane, babul trees, thorn trees, tea brushes, gro-ba (a small white tree that grows mainly in hilly regions), on-bu (a bush-like tree with red flowers that grows near water), K-hres-pa (a strong, durable forest tree used to make food containers, glang-ma (a willow tree used for basketry), and rtsi-shing (the seeds of which are used for making varnish). Fruit bearing trees and certain roots are used for food, as are the leaves of the lia-wa, khumag, and sre-ral, all of which grow in the southeast. Both wild and domestic flowers flourish in Tibet. Among the wild flowers are the blue poppy, lotus, wild pansy, orchid, tsitoy (a light pink flower that grows at high altitudes), shang-dril (a bell-shaped flower, either white, yellow, or maroon that also grows at high altitudes), and ogchi (a red flower that grows in sandy regions).

Climatic Zones of the Tibetan Plateau. For this study, the Tibetan Plateau will be further subdivided into two subzones, primarily due to interaction of the topography and the general circulation. These subzones shown in Figure 3-1, are described below.

Subzone 1—The Southern Mountain Region. This region consists of hills and mountains that help block the northward flow of air from the south and receive most of the summer monsoonal moisture and precipitation. It consists of the Great Himalayan Mountains, Gandise Mountains, the north-south oriented ranges, and all of the southeast lowlands.

Subzone 2—The Northern Highlands and Basins. This area is comprised of arid mountains and hills and desert-like mountain basins that protect the plateau from the cold, dry Siberian air mass. The topography for this region consists of the Kunlun Mountains, Tsaidam Basin, and the Qilian Mountains of northeast Qinghai Province.

MAJOR CLIMATIC CONTROLS

Asiatic (Siberian) High. This high influences the Tibetan highlands from September through April. The cold, dry air associated with the Asiatic high normally only extends to 850 mb and is effectively blocked from reaching the Tibetan Plateau by the Kunlun Mountains. The Asiatic high causes occasional cold outbreaks in lower elevations of the eastern part of the plateau. There are several valleys and basins in the eastern regions where cold air funnels in and becomes trapped, which often makes these locations colder than many of the higher elevations. The high is usually so large and intense it effectively blocks southward moving migratory lows and keeps them well to the north of the plateau.

Topography. In the biggest and highest highland in the world, topography has major effects on climate and is undoubtedly the most important climatic control. The Tibetan Plateau is climatically complex due to its changes in relief. The mountains that surround the plateau have a modifying influence on the climate. The mean elevation is more than 13,100 feet (4,000 meters), which effectively blocks and disrupts the airflow in the lowest one-third of the troposphere. The high and rugged terrain also affects the general circulation. The Kunlun and Altun mountains obstruct the Asiatic high's cold, dense, shallow air of winter much more than the warm air masses of summer that extend to 30,000 feet (9,100 meters).

As a result, much of the airflow that penetrates the plateau is part of the large-scale hemispheric flow, particularly in winter when the low-level air flow is stopped from reaching the plateau. The westerlies that normally prevail over the northern part of the area all year and over the southern part in winter contain little moisture. Approaching air masses either lose most of their cloudiness and precipitation as they cross the mountains or they are entirely blocked. This blocking effect is most noticeable along the southern and western borders where some of the highest peaks are located; these mountains block moisture-bearing air masses from the Indian Ocean and the Mediterranean Sea.

In general, the most extensive cloudiness and the highest precipitation totals occur along the southeast border. This is where low terrain and the orientation of mountain ranges combine to funnel moisture into the southern mountain region.

Elevation has a profound effect on temperature. The thin air and the lack of impurities in the air allow for greatly increased insolation during the day and heat loss at night. This results in a large diurnal temperature variation, which serves as a moderating influence on the climate, particularly in the southern portions of the Tibetan Plateau. The decrease of temperature with height results in cold winter readings in most sections and cold temperatures on the high mountains all year.

Heat Low. This low replaces the Siberian high during the summer. This heat low is a rather weak and diffuse, warm low-pressure system. This system is formed partly as a result of long hours of sunshine that warm the air over the huge Asian landmass. This causes lower pressure and subsequent cyclonic circulation on the plateau. The center is often found over northern India or Pakistan east of the Persian Gulf. The resultant weak flow results in higher temperatures than would be expected, especially along the southern and eastern borders.

Migratory Pressure Systems. Migratory pressure systems do not normally enter the plateau at any time of the year. During winter and spring, migratory lows that exit the Mediterranean Sea are shunted to the south because of the massive Himalayas. These lows primarily influence the southeast lowlands (up to 35° N) and bring southerly winds, cloudiness, and precipitation to that area. Most of the lows that travel across Siberia move along a track well to the north of the Tibetan highlands and exert little or no influence on the area.

Tibetan High. Chapter 2 describes the Tibetan high (see Figure 2-16). The northwestward movement of this high is a requirement for the establishment and the subsequent northward migration of the summer monsoon. This migration corresponds with

MAJOR CLIMATIC CONTROLS

moderate temperatures, increased moisture, and increased precipitation into the southeast portion of the Tibetan Plateau.

Monsoonal Trough. The Himalayas keep this trough from moving into Tibet. The monsoonal trough is responsible for the advection of moisture,

moderated temperatures, and increased precipitation into the southern mountain region and the southeastern sections of the northern highlands and basin region. Maximum precipitation in these regions occurs during the summer months because of the northward advancement of the southwest monsoon; both rain and snow occur (especially in higher elevations).

SPECIAL CLIMATIC CONTROLS

Tibetan Plateau. The Tibetan Plateau is a critical part of the Asian monsoon circulation. In the summer, the mountains are heated by solar radiation, which warms the upper-level air. This insolation raises the pressure surfaces and anchors an upper-tropospheric subtropical ridge across southern Tibet. Once the monsoon rains start, the massive amounts of latent heat released reinforce the ridge. This heating increases the upper-level meridional temperature gradient of the summer monsoon and causes a speed maximum in the upper-tropospheric easterlies (the tropical easterly jet) south of India (see Chapter 2). The plateau cools during winter. It is still a high-altitude radiational heat source although not with the same strength as in summer; higher heights build across the equator to the south. The upper-level temperature and height gradients over southern Asia become more like the rest of the Northern Hemisphere with higher temperatures and heights to the south. A branch of the subtropical jet moves to a mean position just south of the plateau. Oddly enough, the plateau is almost snow-free in fall, winter, and spring because it is too dry. If excessive snow does fall in winter, the following summer monsoon will typically be delayed, and the precipitation will be below average. The plateau also diverts polar continental air from the Siberian high away from India and into southern China and Indochina. The colder temperatures there create a stronger northeast monsoon than in western Asia.

Duststorms. Duststorms occur most frequently during late winter and early spring, but can extend into the summer months near the Qaidam basin in the extreme northern section of the northern highlands. Although nearly every part of the plateau receives duststorms, the most-favored area for formation is in the northern highlands near the Qaidam basin in the Qinghai Province. The northern highlands have the best chance for duststorms because of sparse precipitation and a lack of vegetation in the region. Winds are rarely above 25 knots over large areas, but localized gusty winds may stir up some dust or sand over a small area. Visibility can drop to 800 meters, but rarely for longer than a few minutes. The southeast part of the southern mountain region receives sufficient rainfall to sustain permanent vegetation, which tends to preclude the formation of duststorms. Dust devils

are small vigorous whirlwinds of short duration that carry dust, sand, and debris into the air. Dust devils can occur at any time of the year, but are most likely in the northern highlands and basin regions from late spring to early fall.

Temperatures. In the Tibetan highlands, as in any mountainous region, the effects of the sun's radiation are greater than at lower elevations where impurities and moisture in the air are more concentrated and filter out much of the incoming radiation. During the day, strong radiation at high levels rapidly heats the air near the surface, which tends to moderate the climate somewhat; however, just after sunset a rapid decrease in temperature takes place. Often there is as much as a 27 to 36 Fahrenheit (15 to 20 Celsius) degree diurnal temperature variation. There is also a strong vertical variation in temperature because of the normal decrease in temperature with height. Temperatures range from moderate in the low inhabited valleys in the southeast to severely cold on the high-level glaciers and windswept, snow-covered mountain peaks.

Rainfall Patterns. The mountain ranges help determine rainfall patterns. Since most of the moisture-bearing air masses move in from the Indian Ocean, the exposed southern slopes of the Himalayas receive the greatest amounts of precipitation. Precipitation amounts decrease northward with each succeeding mountain range. By the time the moisture-bearing air reaches northern and western Tibet, there is little, if any, moisture available for cloudiness or precipitation. In the southeast there are many north-south oriented mountain ranges, valleys, and rivers that funnel moisture from the Indian Ocean into the eastern portions of the plateau. Precipitation yields are highest on the windward side or south- and west-facing mountains. Mean annual precipitation amounts vary from 1,000 mm in the southeast to less than 50 mm in the west.

Snow

Depth of Snow. The larger the number of snow days and the longer the duration of snow accumulation, the deeper the snow. Although the elevations are the highest of anywhere in China,

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snow depths do not normally get as deep as other areas of China. Maximum depth of snow ranges from 20 cm along the north slopes of the Himalayas to less than 10 cm in the northwestern sections of the plateau. Along the Zangbo/Yarlung River, maximum snow depths average approximately 10 cm.

Snowfall. In the case of the Tibetan Plateau, elevations seem to play a relatively insignificant role in the number of snowfall days during the winter. In the plateau, the surrounding high mountains act as barriers against the cold northerlies, which leads to poor snow conditions. During summer, the reverse is true; higher elevations receive the brunt of the snowfall because of a combination of low temperatures and increased monsoonal cloudiness. Eastern portions of the northern highlands receive a total of more than 60 days of snowfall annually. Qingshuihe of Qinghai Province has the highest recorded number of mean snow days (113). Elsewhere on the plateau, snowfall averages anywhere from less than 10 to 30 days of snow.

Elevation of Snow Line. For this extremely mountainous area, the snow line represents an important climatic element. It encompasses permanent snow, ice coverage, and glaciers. The plateau, with its surrounding mountains, has the most extensive area of mountain glaciers on earth. The total area above the snow line (representing the glaciated area) amounts to about 29,000 square miles (46,640 sq km), which is 83 percent of the total glacier area of China and 50 percent of the total glacier area of Asia. The height of the snow line varies from 14,400 feet (4,400 meters) on the east Qilan Mountains to 20,300 feet (6,200 meters) in southern and western Xizang(see figure 3-2). The total annual precipitation in glaciated areas averages 2,000 mm in southeastern Xizang and decreases to 200-300 mm in central and western parts of the plateau. The peculiar conditions of solar radiation in the Quinghai-Xizang plateau, in comparison with the surrounding lowlands, apparently influences the height of the snow lines. Due to the vast extent of the plateau, extremely high totals of radiation are absorbed by the plateau; its central and western parts record the highest values in all of China. For this reason, the height of the

snow lines is elevated. Two of the largest glaciated areas are in the western Kunluns and Nyainqentanglha (including the eastern Himalayas). The western Kunlun Mountains, because of their considerable elevation, receive much precipitation from the prevailing westerlies; 1,500 mm or more is likely in this area. The latter range receives most of its snow from May to September when the southwest monsoon brings an extensive blanket of cloudiness causing frequent heavy snowfalls in the high mountains.

Length of Snow Cover Period. The mean length of the snow cover period represents the number of days between the (mean) first and last dates of snow cover. The mean length of the snow-cover period at any location depends on two aspects, latitude and elevation above sea level. The plateau's high elevations are responsible for the long period of snowfall annually along with its higher latitude. Excluding the glaciated, high-mountain regions (which experience a year-round snow cover period), the longest recorded duration of snow cover occurs in the mountains of Qinghai. Litang, with an elevation 13,000 feet (3,900 meters), has 288 days of snow cover. Tongde, with an elevation of 10,800 feet (3,300 meters), has 280 days. The mean length of snow-cover period varies from less than 50 days in the southeast to more than 200 days in the mountains of the Qinghai Province. Mean first snowfall date occurs in September and mean last snowfall date is in mid-June, especially the northern highlands and mountainous areas in the southern mountain region. This allows snow melt to occur only during the 2 to 3 months of summer.

Permafrost. Permafrost is an area of permanently frozen soil or bedrock beneath the surface of the earth in which the temperature has been below freezing continuously from a few to several thousand years. This frost exists where summer heating fails to descend to the base of the layer of frozen ground. An area is likely to have permafrost when mean annual temperature is 23°F (-5°C) or lower. The formation of permafrost depends more on elevation than on latitude. Permafrost covers almost the entire plateau except for the southeast and the Brahmaputra River valley. These areas only have frozen soil on a seasonal basis. The permafrost

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Mountains	Height of Snow Line (meters)	Area (square km)
Qilan	4,300-5,200	1,973
Kunlun	4,700-5,800	11,639
Pamirs	5,500-5,700	2,258
Karakorum	5,100-5,400	3,265
Tanggula	5,400-5,700	2,082
Gandise	5,800-6,000	2,188
Nyainqentanglha	4,200-5,700	7,536
Hengduan	4,600-5,600	1,456
Himalayas	4,300-6,200	11,055

Figure 3-2. Height of Snow Line and Area Coverage. The figure shows height of snow line in meters and coverage in square kilometers for various locations on the Tibetan Plateau.

line does not appear until the 13,600 -foot (4,150-meter) point in the Kunlun Mountains and the 16,400-foot (5,000-meter) level in the Himalayas. On the Tibetan Plateau, the layer of frozen soil thickens by 66 feet (20 meters) for every 328 feet (100 meters) above the permafrost line. The lower the winter temperatures and the longer the duration of temperatures below freezing, the deeper the soil will be frozen. Maximum frozen soil ranges from zero in the southeast to more than 8 feet (2.5 meters) in the northwestern portion of the plateau. At higher elevations, a complete thaw does not come until late August. Shortly after that, freezing begins again.

Local Winds. Mountain and valley winds are defined in Chapter 2. In the Tibetan Plateau, wind speeds can reach as much as 30 to 35 knots in the mountain passes with valley winds. Mountain wind is usually weaker than valley wind unless coupled with other forces. These winds occur during any season; the direction depends on local terrain. Local wind systems, which may add to the large-scale diurnal and seasonal circulations, can be overwhelmed by these circulations, or can override them when the large-scale circulation is weak.

Bora. Bora is a local term and is normally applied to the northeast wind on the Dalmatian coast of Yugoslavia in winter. It is now applied to many other areas of the world. It is caused by very cold air that accumulates over the glaciers and high snowfields and spills down the steep mountain slopes, canyons, and valleys. The steeper the slope, the stronger the bora will be. Often this wind is so strong that the strong cold air offsets dynamic temperature rises during its descent down the lee slopes. This wind occurs most frequently in the fall and winter and is observed in the valleys of the eastern sections of the southern mountain region. It is at maximum intensity between the hours of 06L to 08L. These winds are very cold and dry and can reach speeds in excess of 40 knots. Because these winds are so dry, cloudiness can evaporate into cloudless conditions. At times, the bora can be so violent that moderate-to-severe turbulence is possible in the lower layers of the atmosphere.

Föhn. Because of the many mountain ranges within the plateau, föhns are likely just about anywhere and during any season. Because the large-scale winds are mainly out of the west on the plateau,

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the most likely spots for the development of föhns are east of mountains or mountain ranges. This is best seen in the following areas: the eastern portion of the southern mountain region, along the Himalayan and Karakoram ranges, in the western portions of the southern mountain region, and in the northern highlands and basin regions. These winds can cause significant snow melt from the resulting high temperatures, but flooding seldom happens because föhns occur on a local scale. Besides rapidly warming temperatures, these winds bring low humidities and excellent visibility. The presence of altocumulus standing lenticular and rather flat, cumuliform clouds that obscure the peaks of the mountains and shroud the high-level windward slopes indicate a föhn is occurring or will occur soon. Because of the low humidity, leeward slopes are often free of precipitation and clouds. A föhn may not always reach the valley floor as a warm current. If a shallow, cold dome exists in the lowlands, the föhn current moves over it. Alternatively, a shallow, cold dome could develop at night and lift the föhn above the valley floor. When the warm air is lifted above the valley floor, this could cause low-level wind shear during aircraft departures and landings. Under extreme conditions, mountain-wave turbulence can develop as a result of the air that is forced over the mountains.

Land/Lake Breezes. Land/lake breezes require weak synoptic flow and a sharp temperature contrast. The best chance for this is during the summer when the westerlies are weak and the plateau has begun to heat up. Most of the lakes are located between 30° to 38° N in a east-west line. These breezes typically cause afternoon cloudiness and precipitation 12 to 24 miles (20 to 40 km) inland from shore. Gangca, on the northern shore of Qinghai Lake, is the best example of land/lake breezes. This reporting station receives more cloudiness and precipitation than most other reporting sites in the Qinghai Province.

• Examples.

Mangya. Wind directions are from the north-northwest or north-northeast from dawn to evening. Since the prevailing geostrophic flow is from the west-northwest, the daytime circulation is an upslope wind at the southwest of the Tsaidam basin; the dawn wind direction is governed by the large scale circulation created by the Tibetan Plateau. The larger circulation pattern overwhelms the locally-generated downslope wind.

Gar Dzong. This is in a broad, south-southeast to north-northwest oriented valley where a simple mountain-valley circulation should be expected. At dawn, the expected mountain breeze blows from the south-southeast but with remarkable intensity that is attributed to reinforcement by the seasonal large-scale circulation from the south. The winds are weakest at noon when the ascending valley breeze (north-northwest), the gradient flow (southwest), and large-scale circulation (down the valley from the south-southeast) are all of equal intensity.

Heiho. North-northeast winds prevail during the night; this is a mountain breeze from a nearby ridge. During the day, valley breezes from the southwest are strong, but they have large variability. This is because the gradient wind and valley breeze act together to strengthen the southwest breeze.

Phari Dzong. This station is near the origin of a valley that lies south-north and crosses the Himalayas. The ascending valley breeze (southerly), prevails during the entire day, even at dawn. The southerly seasonal circulation overwhelms the weak nocturnal mountain breeze.

General. Winter is the longest season of the year on the plateau. The moisture associated with the southerly winds of summer has moved south. This decreases cloud cover and precipitation from north to south. The Siberian high is at its strongest with frequent cold outbreaks that move south into the eastern lowlands and valleys. Occasional migratory lows move from the Mediterranean toward the plateau, but they are shunted to the south of the plateau by the Himalayas. These transitory systems bring moist, southerly winds, occasional periods of

cloudiness, increased precipitation, and poor visibility to the southern mountain region. By the end of December, cold, dry air has settled into the entire plateau except for some locations at lower elevations in the extreme south. Because of the high elevations, the long nights, and the cooling effect of the glacier regions, heat loss is at a maximum. This heat loss causes bitterly cold temperatures. The lack of southerly flow and its associated moisture causes a decrease in the amount of snowfall days and accumulations.

Sky Cover. By winter, cloudiness decreases dramatically (see Figure 3-3). Most clouds are stratiform throughout the region, but ceilings less than 1,000 feet occur less than 5 percent of the time. Unstable conditions associated with afternoon heating and enhanced by orographic lifting cause early morning stratus clouds to lift into a stratocumulus layer. There are two areas of maximum cloudiness during winter. The area west of 85° E is influenced by instability from upper-air troughs that bring moisture from the Mediterranean Sea. This moisture is normally in the form of middle and high clouds that migrate across the mountain ranges in the western parts of both the northern highlands and the southern mountain region. The southeastern portion of the southern mountain region also feels the effects of the migratory lows that pass to the south of the region. These migratory lows bring brief periods of southerly flow and low cloudiness. Ceilings occasionally drop down to as low as 200 to 1,000 feet in some of the river valleys.

During winter, cloud cover in the southern mountain region occurs approximately 60 percent of the time at locations in the extreme eastern portions and 30 percent of the time north of the Himalayas along the Brahmaputra River valley. The northern highlands and basins are cloudy 60 percent of the time in extreme eastern sections of the region and 40 percent of the time in the northwest.

Southern Mountain Region. Ceilings less than 3,000 feet show a decrease by 50 percent from summer. The highest percentages of low clouds occur at night or during the early morning, especially from November through January. The plateau has prevailing westerly or northerly flow

that keeps the area drier than in the summer months. Northerly flow tends to hold moisture south of the area and enhances the nocturnal downslope flow in southeast portions of the plateau. This keeps low ceilings to a minimum in that area. During afternoon, however, the prevailing circulation pattern is weakened by upslope flow. This increases cloud coverage in the northern extremity of the eastern part of the region. Cloud cover occurs 50 to 60 percent of the time in eastern areas and 30-40 percent of the time in all other areas. Ceilings less than 3,000 feet occur anywhere from less than 1 percent in the west to as much as 48 percent of the time in the mountains. The latter occurs in Pagri, which is located in the foothills of the Himalayan Mountains, during late winter when rain and thunderstorms make their appearance as the monsoon trough begins to move north (see Figure 3-4).

Northern Highlands and Basins Region. Cloud cover decreases from south to north and from east to west. The north and west are much drier due to the distance from the monsoonal trough and the many lakes and rivers that provide additional sources for moisture. On average, cloud cover occurs 30 to 40 percent of the time in the north and west and 40 to 50 percent of the time in the south and east. Ceilings less than 3,000 feet occur less than 5 percent of the time in the northwest and increase to approximately 20 percent in the east. In March, most areas see a dramatic increase in ceilings less than 3,000 feet. As spring nears, days get longer and the monsoon trough approaches from the south. This provides both the moisture and heat to fuel heavier showers and thunderstorms in the southern part of this region.

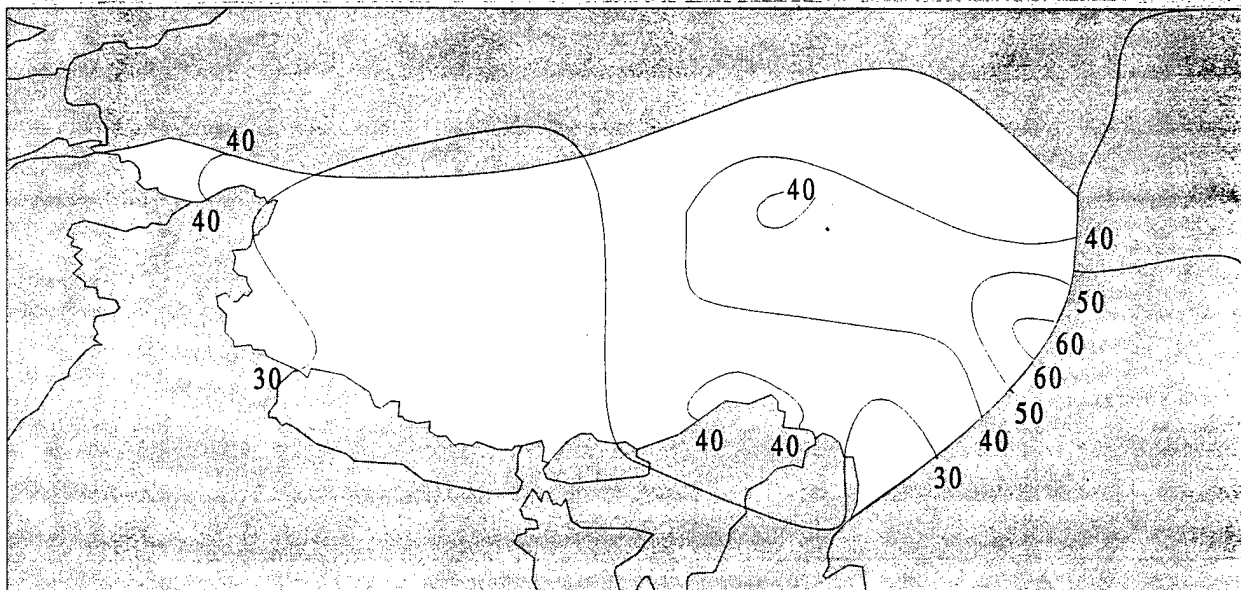


Figure 3-3. January Ceilings. The isopleths represent the frequency of cloud ceilings at all altitudes for local noon.

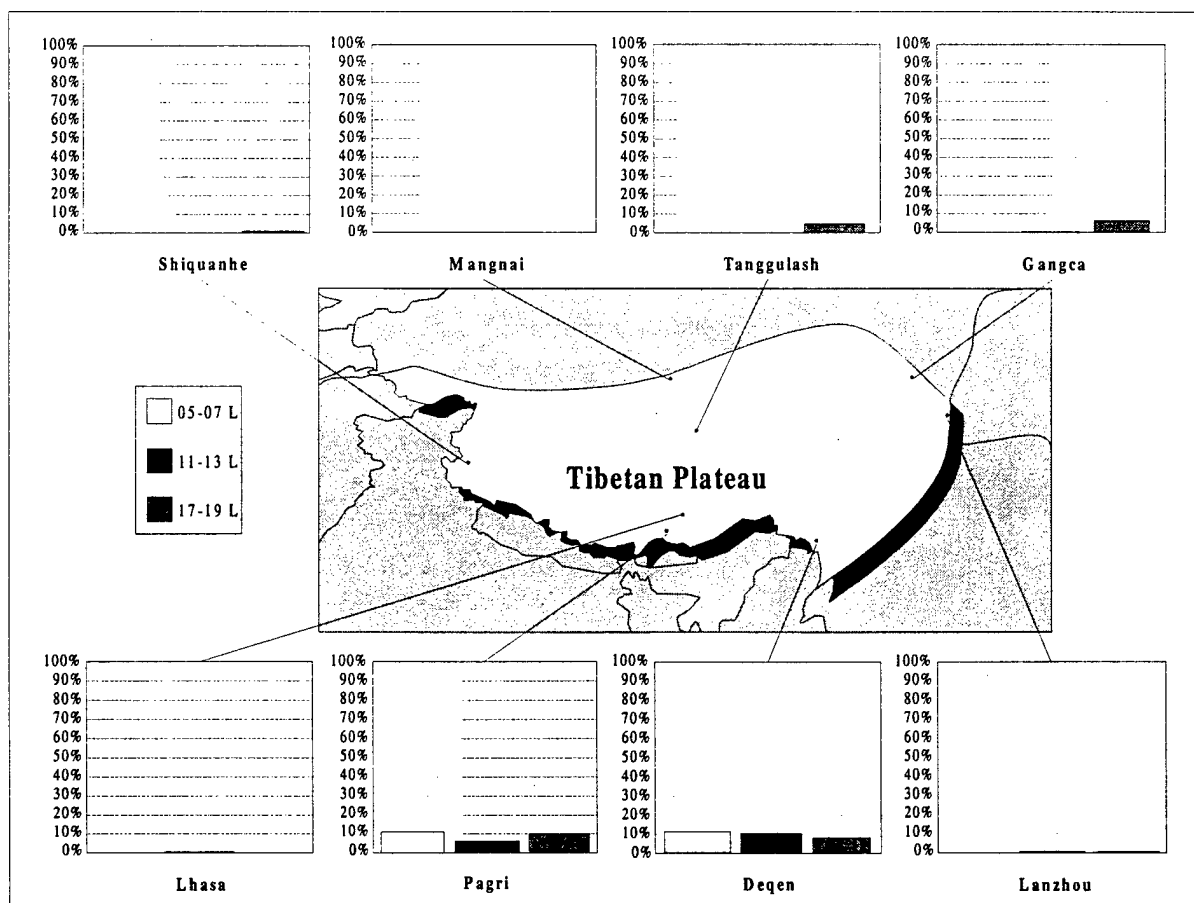


Figure 3-4. January Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. The main obstructions to visibility during winter are fog, blowing snow, and blowing sand. In winter, strong winds that develop in mountain passes and high mountain peaks create potential for blowing snow. In the barren northwest where moisture is limited, blowing sand and dust can occasionally drop visibility to less than 4,800 meters, particularly during the afternoon when winds are the strongest and instability is the greatest. Higher frequencies of low visibility as a result of blowing sand occur later in the season as the ground begins to dry up from the months of low precipitation amounts (see Figure 3-5). The best areas for fog formation are in the southeastern valleys where there are abundant moisture sources. Radiation fog forms at night in the lower elevations and usually stays through midmorning. During the afternoon hours, some of the mountain locations report visibility problems from clouds that have either lifted to their elevation or formed on them.

Southern Mountain Region. Fog causes most of the visibility restrictions in the southeast. It occurs 1 to 3 days per month. Blowing dust is the most

probable obstruction to visibility in the western portions of the region, occurring on average 1 to 2 days per month. In the Himalaya and the Bayan Har mountains, blowing snow frequently develops above 9,800 feet (3,000 meters), but visibility below 4,800 meters occurs less than 5 percent of the time through the winter. Along the watershed of the southeast, visibility below 4,800 meters occurs 5 percent of the time in November and increases to 15 percent of the time by late March when a moisture influx from the Indian Ocean occurs.

Northern Highlands and Basins. As in the southern mountain region, visibility less than 4,800 meters occurs less than 5 percent of the time. For a few of the locations that are below 6,600 feet (2,000 meters) in elevation on the eastern edge of the highlands, visibility below 4,800 meters occurs 10 to 15 percent of the time. Fog occurs in these areas 2 to 3 days per month. Cold air from the Siberian high combines with the warm waters of the Huang (Yellow) River to produce an abundance of fog. Lanzhou's visibility decreases to less than 4,800 meters about 37 percent of the time during December and January.

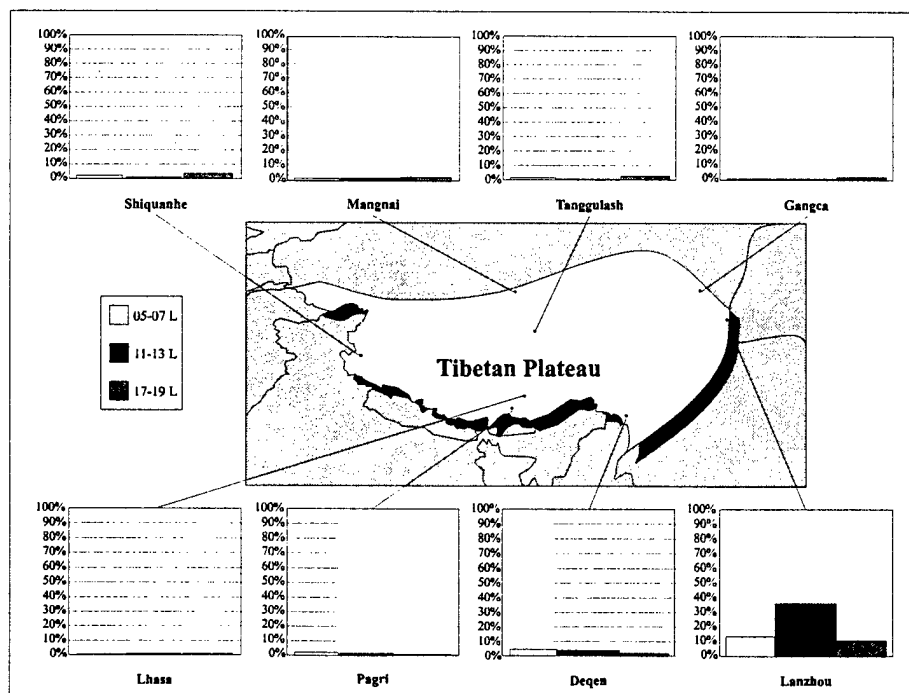


Figure 3-5. January Visibility below 4,800 Meters. The graphs show a breakdown of the percentage of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Terrain does much to shape local wind circulations; each location is a little different. At many locations, in addition to the orientation of mountain ranges, mountain and valley winds strongly affect both the direction and wind speed as well as offset or enhance the large-scale circulation patterns (see Figure 3-6). Wind speeds tend to be stronger during winter since the westerlies are stronger. Because many locations are at or above the 500-mb level, normal wind flow is from a westerly direction. Along the northern and eastern borders of the plateau, wind directions favor a northeasterly direction when under the influence of the Siberian high, particularly for elevations below 6,600 feet (2,000 meters).

Southern Mountain Region. Wind directions vary in accordance with the orientation of mountain ranges and the location of key topographical features (lakes, mountains, etc.). Winds are normally from the west with an average speed of approximately 3 to 5 knots. Speeds in open valley locations average 6 to 15 knots. Because many locations are protected by mountains, calm winds occur 30 to 50 percent of the time at night and 10 to 20 percent of the time during the day. In valley locations, strong winds occur infrequently. At higher elevations on mountain slopes, near mountain tops, and in passes it is probable that strong wind speeds occur frequently. The bora is typical of this type of wind. The bora is generated by a very cold air mass that accumulates over the glaciers and high snow

fields then spills down the mountain slopes into canyons and valleys. The steeper the slope, the stronger the bora. This wind occurs mostly along the south faces of the Himalayas. The best locations for the bora are in the valleys of the eastern part of the region because much of the cold air from the northern plateau flows southward into the north-south oriented valleys. These cold, dry winds may reach speeds near 40 knots. Lijiang, in the extreme southeast, received a maximum wind of 56 knots. It was probably caused by a bora wind.

Northern Highlands and Basins. Winds are westerly throughout winter. Because of the stronger upper-level flow and the open plains and basins, westerly surface winds dominate with few local circulations. Wind speeds across the region average approximately 6 to 15 knots. A few locations in the south-central portion of the region average winds of 15-24 knots because these locations lack any mountains to block the west winds. Calm winds occur only 10 to 20 percent of the time in northern and western sections of the region where the strength of the jet stream makes its presence known. Calm winds occur 30 to 50 percent of the time in southern and eastern sections. Strong winds are rare, but speeds of 40 to 50 knots have occurred. Boras are not as common in the northern highlands as they are in the south. Nagqu, in the south-central portion of the region, recorded a maximum gust of 58 knots during January and February.

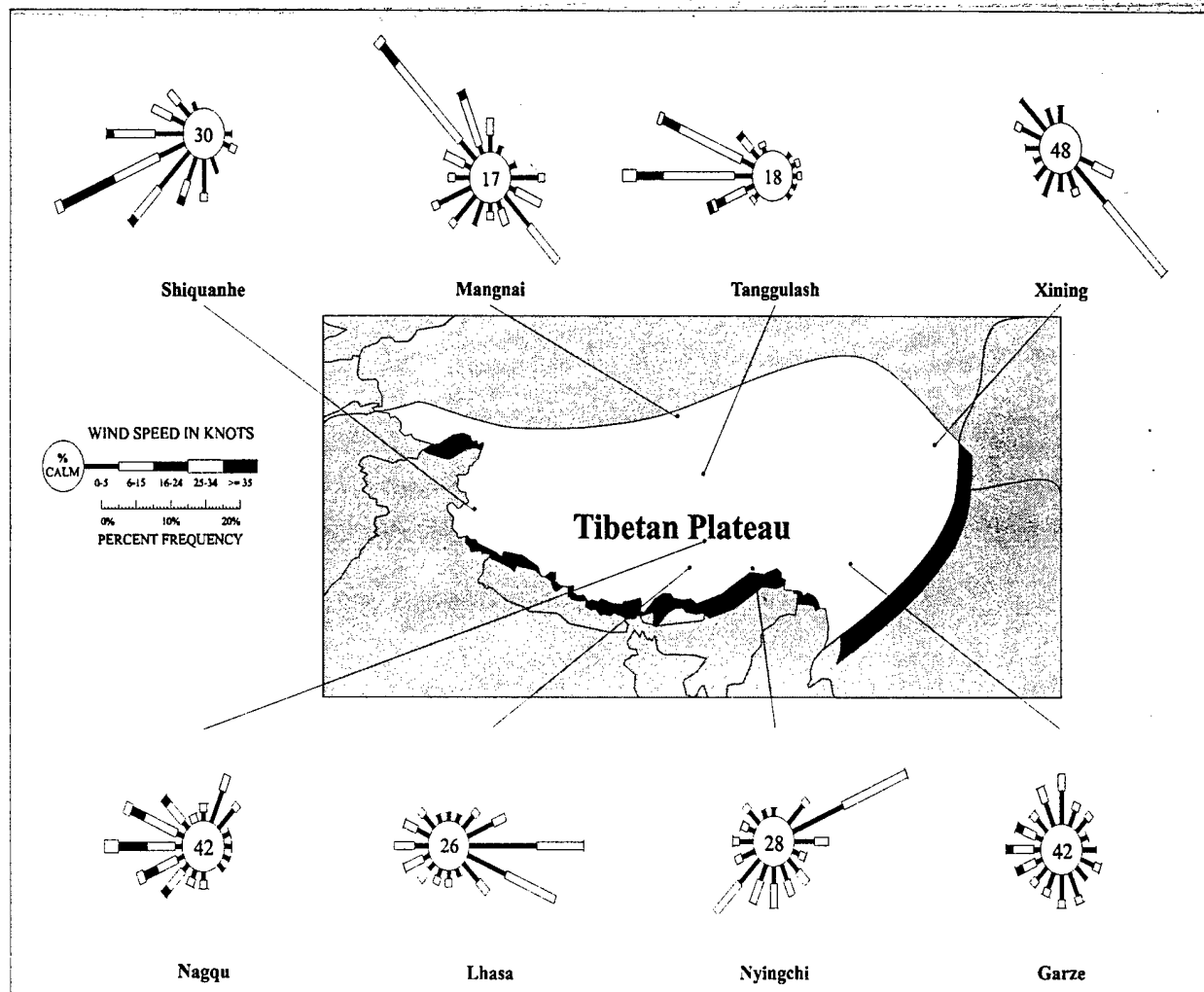


Figure 3-6. January Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Winter

Winds Aloft. The polar jet forms and remains north of the Himalayas at the 300-mb level. The subtropical jet stream axis is located south of the plateau at the 200-mb level and is stronger than the polar jet (see Figure 3-7). Wudu is on the very eastern section of Tibet. The 850- and 750-mb level wind roses in Figure 3-7 are not representative for areas in Tibet that have higher terrain.

Northern Highland and Basins. The polar jet axis is located at the 300-mb level north of the Kunlun Mountains. Usually the wind speeds are much lower

than in the southern mountain region. The jet stream wind speeds are approximately 70 knots in the west and increase to 80 knots in the east. Wind speeds decrease to 55 knots at 300 mb and to about 25 to 30 knots at 500 mb.

Southern Mountain Region. Winds in the southern mountain region are stronger because the region is generally close to the subtropical jet axis, which generally has stronger winds. Wind speed is approximately 20 knots stronger at all levels on the southern periphery of the region.

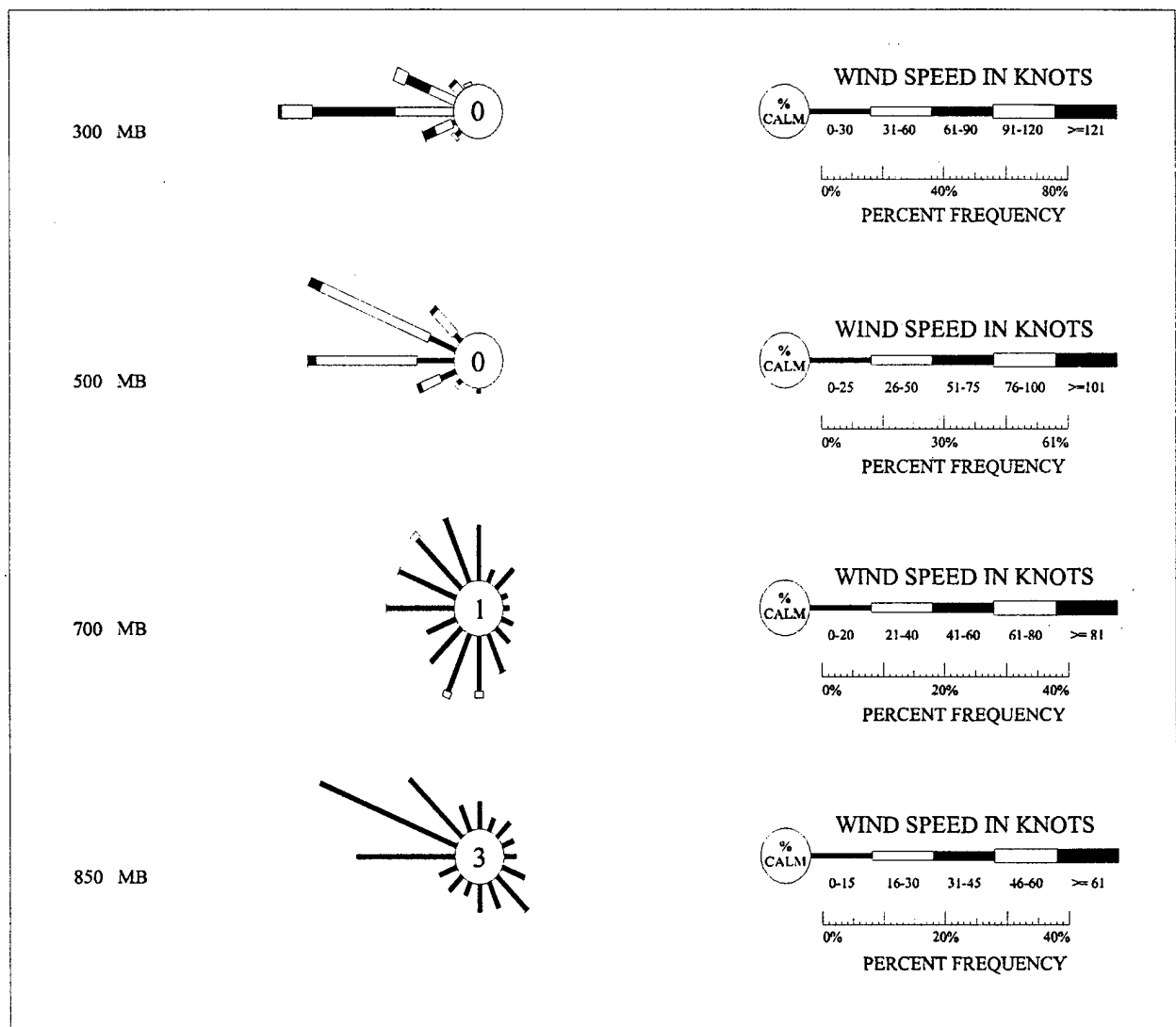


Figure 3-7. January Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Wudu. Note: Each wind rose has a tailored legend.

Precipitation. This is the driest season, but some pockets of moisture left from the summer make their way across the mountains from the west (see Figures 3-8 and 3-9). Although the elevation is high, all types of precipitation occur on the plateau, even during the winter. Snow is the most likely form of precipitation, but rain occurs throughout the season because the temperature rises during the day from solar radiation. Thunderstorms occur late in the season as the plateau begins to heat and monsoon moisture begins its northward trek. Though winter has more snow days than summer, less snow falls in the winter than the summer because of the lack of large quantities of moisture.

Southern Mountain Region.

Snow. Snowfall day averages in the region increase in winter to about 6 days per month in the east and about 4 days per month in the west. The southern mountain region gets more snow during the winter than the northern highlands. Most snowfall occurs in the southeast on the western slopes of the north-south oriented mountain ranges. Degen receives the maximum for the region, an average of approximately 20 days of snowfall during the months of February and March. Snowfall days increase from a minimum in November to a maximum during March due to the increased moisture supplied from the Indian Ocean. Snow depth varies based on location. With an average of 30 cm, Degen has the highest mean snow depth within the region.

Thunderstorms/Rain/Hail. Thunderstorms are not a problem during the winter mainly because the plateau is a heat sink during this season. Thunderstorms are most likely to occur during November and March but are rare from December to February. In the extreme southeast (south of 30° N), thunderstorms average about 1 day per month. Most thunderstorms and showers are orographically induced and occur on the upwind side of mountains. These storms lack the heating and strong lifting that is common during the

summer. Rain days decrease considerably from fall to a minimum in January or February then begin to rise again by late winter. Although the elevation is high, the region has a fairly high number of days with rain. Most of the liquid precipitation occurs during the day due to the huge temperature drops that occur at night. Rain averages from 3 days in the west to about 8 days in the southeast. The central portion appears to be fairly dry. Precipitation amounts are low and yield less than 5 mm in the west to 10 mm in the east. Lhasa and Xigaze, for example, receive an average of 1 rain day a month. Hail is very scarce. Hail occurs on only 1 day in March and is normally small, less than 5 mm.

Northern Highlands and Basins.

Snow. Winter receives about as many snow days as the southern mountain region, but snowfall amounts are often low. The southeastern portions of the northern highlands and basins are more likely to receive more snow days; most of this snowfall is on the south or east-facing mountains (windward sides). Snow falls 2 days in the extreme north and 7 days in the Tanggula Mountains in the south. Some locations can receive as many as 19 days of snowfall; most snow days are recorded in March.

Thunderstorms/Rain/Hail. Thunderstorm frequency is lower in the northern highlands than in the southern mountain region. The extreme southeast section of the region only receives 1 day of activity in March when heating and moisture begin to increase. Rain days are far less usual in this region than the southern mountain region. Because this region is slightly colder and drier, rain is less likely than snow. The best chances for rain are the months closest to the transition seasons. Rain averages about 1 to 2 days per month with as many as 5 days possible during March in the southeast part of the region. Precipitation amounts are low and yield only 5 mm per month. Hail sizes of less than 5 mm are possible during March at a few isolated locations in the Tanggula Mountains.

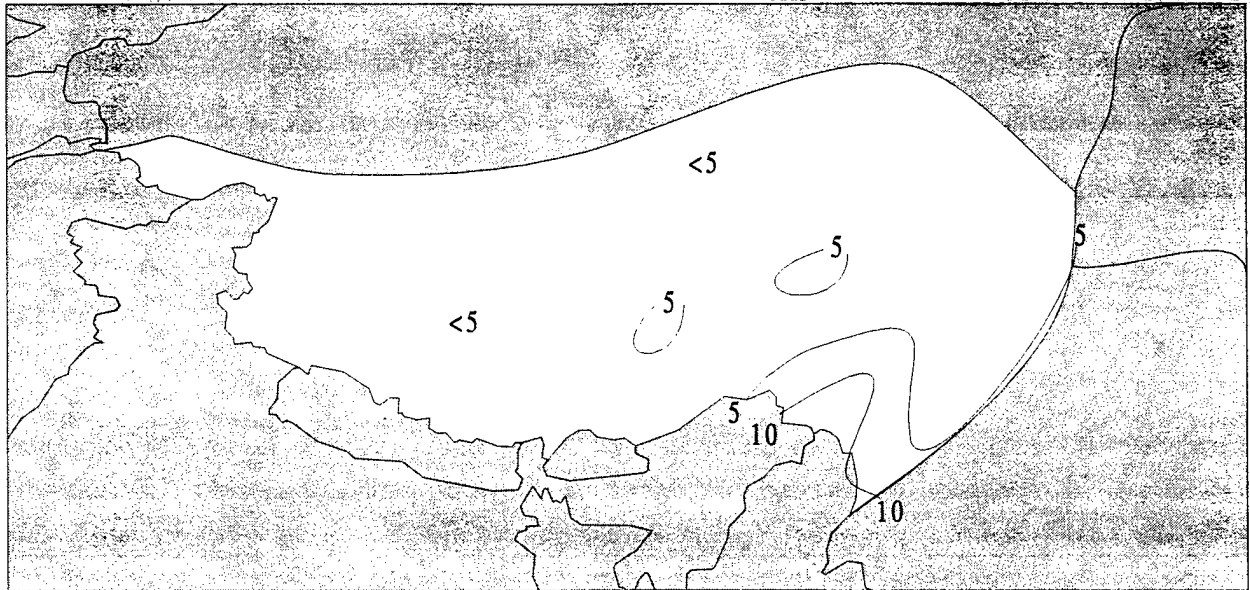


Figure 3-8. January Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

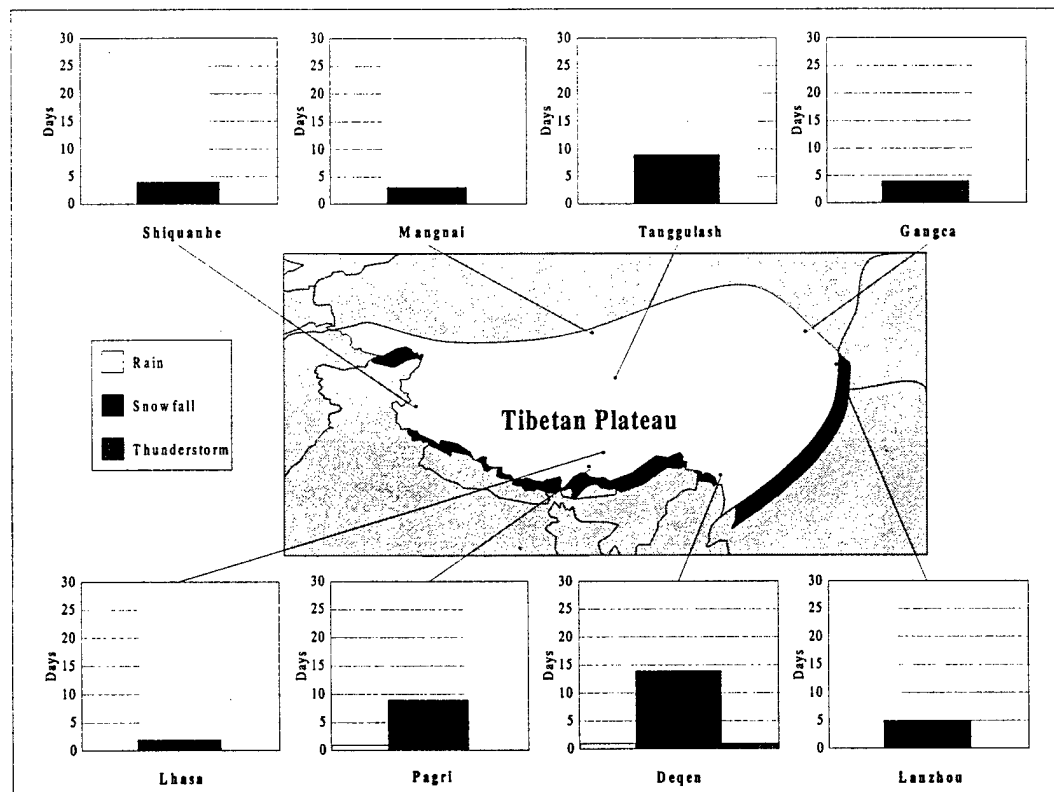


Figure 3-9. January Mean Rain, Snow, and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on average occurrences at scattered locations within the Tibetan Plateau.

Temperatures. Winter is the coldest season for the Tibetan Plateau. January maximum temperatures range from a bitterly cold temperature of 16°F (-9°C) in the northern highlands to 55°F (13°C) in the southern mountain region where warmer temperatures prevail even in winter (see Figure 3-10). The diurnal temperature range is great. Strong radiation at high levels heats the air near the surface during the day, but when the sun sets, a rapid decrease in temperatures takes place. Because of very high mountains, large temperature variations occur from the milder temperatures of the lowland valleys of the southeast to the severely cold regions of the high, windswept, snow-covered mountain peaks. In some regions, there is as much as a 36 Fahrenheit (20 Celsius) degree temperature change from maximum to minimum.

Southern Mountains Region. This region is warmer than the northern highlands for several reasons: it is farther from the cold air of the Siberian high, it is lower in latitude, its average elevation is lower (particularly in the southeast), the downward movement of air is warmed by adiabatic

compression, and lows passing to the south generate warming southerly winds. Mean maximum temperatures range from 64° to 21°F (18° to -6°C); mean minimums range from 43° to -2°F (6° to -19°C). Deqen, with an elevation of 11,444 feet (3,488 meters) had an extreme maximum temperature of 84°F (29°C) during March; Shiquanhe (elevation of 14,039 feet (4,279 meters)), in extreme western Tibet, reported an absolute minimum temperature of -33°F (-36°C) during January.

Northern Highlands and Basins. This is the coldest region of the plateau because it is closest to the cold air of the Siberian high and is farther north than the southern mountain region. Mean maximum temperatures range from 52° to 16°F (11° to -9°C). Mean minimums drop to an average of 32° to -11°F (0° to -24°C) (see Figure 3-11). Lanzhou (elevation 4,980 feet (1,518 meters)), which is located in a valley, recorded a extreme maximum temperature of 78°F (26°C) in March. This was probably the result of a foehn wind event. Madoi (elevation of 14,019 feet (4,273 meters)) recorded -53°F (-47°C) for extreme minimum temperature.

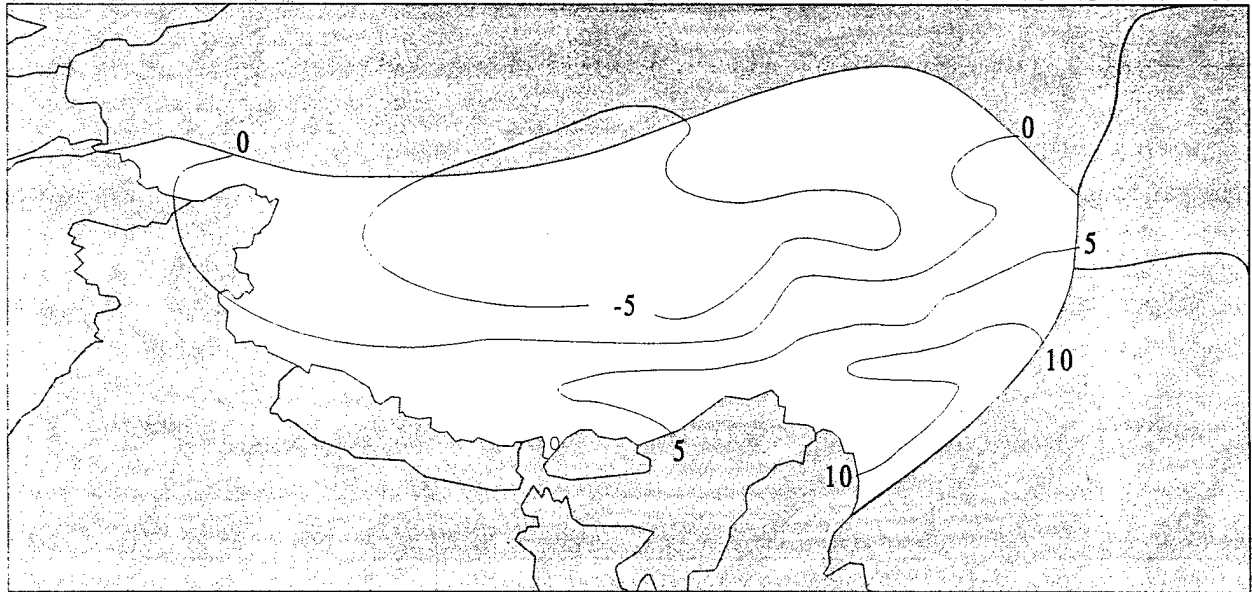


Figure 3-10. January Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for winter.

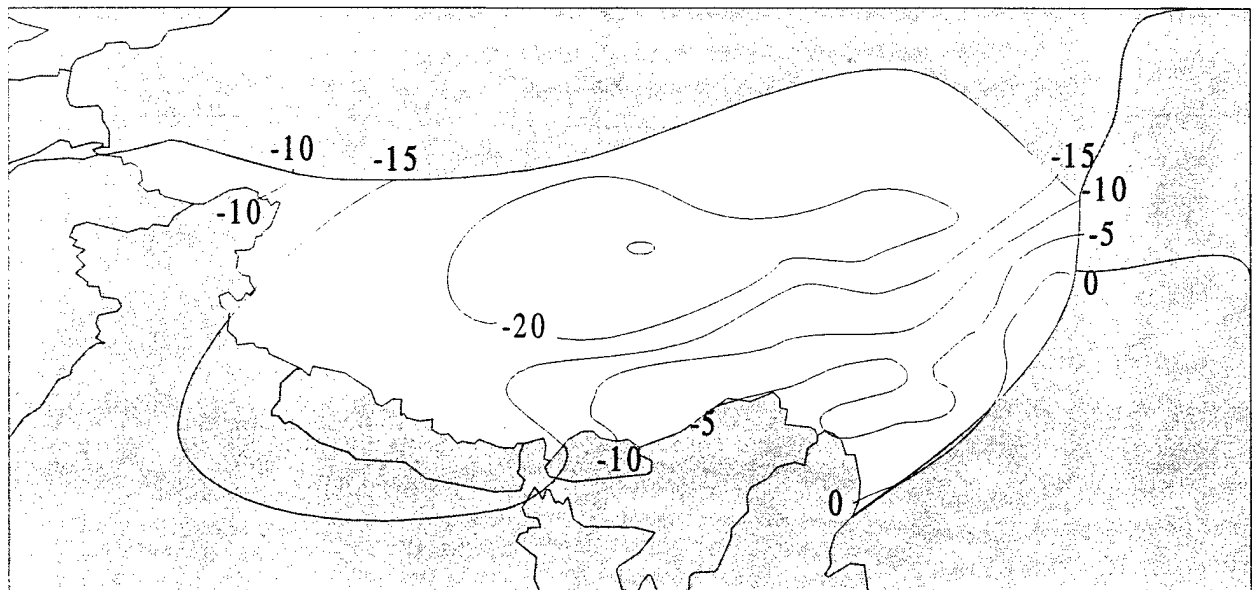


Figure 3-11. January Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average low temperatures for winter.

Hazards.

Turbulence. During winter, the jet stream branches west of the Tibetan Plateau. One branch goes north and the other south. The two branches meet over Japan. Wind speeds increase in eastern Tibet partly because of this downstream confluence and the speeds gradually weaken westward of that point. Clear air turbulence can be expected near the tropopause. Heights of the tropopause in winter are 33,000 to 46,000 feet (10 to 14 km). This turbulence can occur nearly anywhere on the plateau, but the most likely area is in the eastern part of the plateau where the winds strengthen.

Even though Tibet is between the jet streams, wind speeds are west to southwest at 25 to 35 knots between 18,000 to 25,000 feet (5 to 8 km). This creates potential for moderate-to-severe mountain-wave turbulence. The best chance for mountain-wave turbulence is in the winter when westerlies are a little stronger. Most likely, this type of turbulence can be expected below 20,000 feet (6 km) west of 90° E on the lee side (north) of the Great Himalayas, east of the Karakorum Mountains in western Tibet, and over the north-south oriented ranges in southeast parts of the plateau.

Icing. During winter, the mean height of the freezing level is at the surface over most of the plateau. In the heat of the day, the freezing level lifts to between 4,000 to 6,000 feet (1 to 2 km) above most of the terrain, but remains at the surface in the mountains. Tops of icing generally extend to 30,000 feet (9 km) MSL. The most severe icing conditions are found in the upper half of tall cumulus clouds prior to the time they reach the thunderstorm stage

and immediately before rain begins to fall. Mixed icing can be expected during the dissipation stage when clouds flatten into layers of stratocumulus and altocumulus. Under most circumstances, thunderstorms only cover a small portion of the area and are easily circumnavigated so they pose no threat to aircraft. Clear icing is the most common type found in thunderstorms. Stratus and stratocumulus clouds usually have rime ice during the winter. Light-to-moderate mixed (clear and rime) icing is possible with altocumulus. The level where icing would be heaviest is from 15,000 feet to 25,000 feet (5 to 8 km) MSL. Cirrus and altostratus are normally made up entirely of ice crystals with little or no water vapor so icing is negligible. Winter has a lower probability of icing due to the dryness of the atmosphere.

Hail. Winter has a much lower probability of hail than summer because of lack of heating. Hail does occur occasionally and can pose a problem to not only aircraft, but also to ground operations. In China, small hail is considered less than 5 mm and large hail is greater than or equal to 5 mm. Winter receives small hail. The highest frequency of hail occurs east of 95° E and south of 35° N in the eastern half of the plateau. The most likely areas for hail are over mountains rather than on plains and valleys because the uneven heating and dynamic disturbances that occur over the mountains cause strong convection. More hailstorms are found on windward slopes than on leeward slopes and on southern slopes rather than northern slopes. Danger to aircraft can occur over mountains, on windward slopes, and on the southern slopes of mountain ranges.

Winter

Trafficability. The Tibetan Plateau is the world's highest plateau. It is surrounded by massive mountains, many of which have permanent snowcaps and glaciers. The plateau is a mixture of high mountains, hills, and intermontane plains and alpine meadows. It has many wide valleys, basins, lakes, and salt flats. Slopes are gentle to moderate on the plains and hills and steep in the mountains. Most of the soils are coarse-to-medium grained with fine soils in basins and salt flats. In some high mountain meadows, highly organic and peat soils overlay permafrost. During dry weather, movement conditions are fair to good on the plains, in the wide valleys, on the salt flats, and in most of the basins. Movement conditions are poor to unsuitable in

most hills and mountains due to the steep slopes and rugged terrain. Movement is possible in some broad mountain meadows, especially when they are frozen.

The Sichuan basin is an area in south central China. Within this basin are low mountains, hills, and many streams and terraces which consist of mostly fine-grained soils. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. In the dry season, conditions in the hills and plains are poor to good. Conditions depend on local agricultural practices. Movement conditions are unsuitable in flooded rice paddies and in highly terraced areas.

General. During April, the great Siberian high weakens because of increased insolation. By the end of May, the high is almost completely gone. The Pakistani heat low develops as the days get longer and the Asian landmass begins to heat up. Occasional migratory lows continue to migrate to the south of the Himalayas and produce cloudiness, precipitation, and visibility problems. By April,

moisture associated with the monsoonal trough has made its appearance in the southern mountain region and begins to affect the southern section of the northern highlands by May. Temperatures begin to increase as do occurrences of thunderstorms and showers. The number of days with precipitation, the amounts of precipitation, and the chance for severe thunderstorms all increase.

Sky Cover. Low cloudiness is widespread in the western and the southeastern parts of the plateau with lower percentage of clouds in the central through the north-central areas. Sky cover at most locations shows a gradual increase through the spring, although local variations exist because of terrain (see Figure 3-12). Most clouds are stratus with bases from 1,000 to 2,000 feet from late evening until midmorning. These clouds lift into stratocumulus and cumulus decks with bases from 2,000 to 3,000 feet by afternoon because of afternoon heating.

Southern Mountains Region. Occasional migratory lows and the northward push of the monsoonal trough act to increase cloudiness into the eastern portion of the southern mountain region. Western portions have increased cloudiness as upper-level troughs bring moisture from the Mediterranean Sea across the western extent of the Himalayas. Cloudiness decreases eastward from the Himalayas as the air mass takes on more continental characteristics. Cloudiness occurs 60 to 70 percent of the time in eastern portions, but decreases to 30 to 50 percent in western and central portions. Highest frequencies occur during the afternoons as stratocumulus ceilings form in the heat of the day. Higher frequencies of ceilings less than 3,000 feet occur high in the Himalayas and on the western side of mountain chains that are oriented

north to south (see Figure 3-13). Ceilings less than 3,000 feet occur 40 to 50 percent of the time in the Himalayas and 20 to 30 percent of the time in the southeastern river valleys and ranges. From the central to the western parts of the region, the frequency of cloudiness lowers to less than 5 percent of the time. This would indicate that most cloudiness that comes across the western extension of the Himalayas is sheared off and only high clouds in the range of 15,000 to 25,000 feet remain.

Northern Highland and Basins. Migratory lows do not impact the northern zone as much as the southern zone. The monsoonal trough starts to increase cloudiness by early May, although its mean position is located south of the area. Upper-level troughs bring cloudiness into western portions of the northern highlands before they dissipate in central parts of the region. Cloudiness occurs 60 to 70 percent of the time in the east and decreases to 30 to 40 percent in the central and western portions of the region. Much like the south, highest frequencies occur in the afternoon as cumulus or stratocumulus. Ceilings less than 3,000 feet occur 20 to 40 percent of the time in the eastern portion of the region and decrease to less than 5 percent in the western two-thirds of the region. Eastern portions have greater access to moisture from the monsoonal trough and the many river valleys that are in this portion of the plateau.

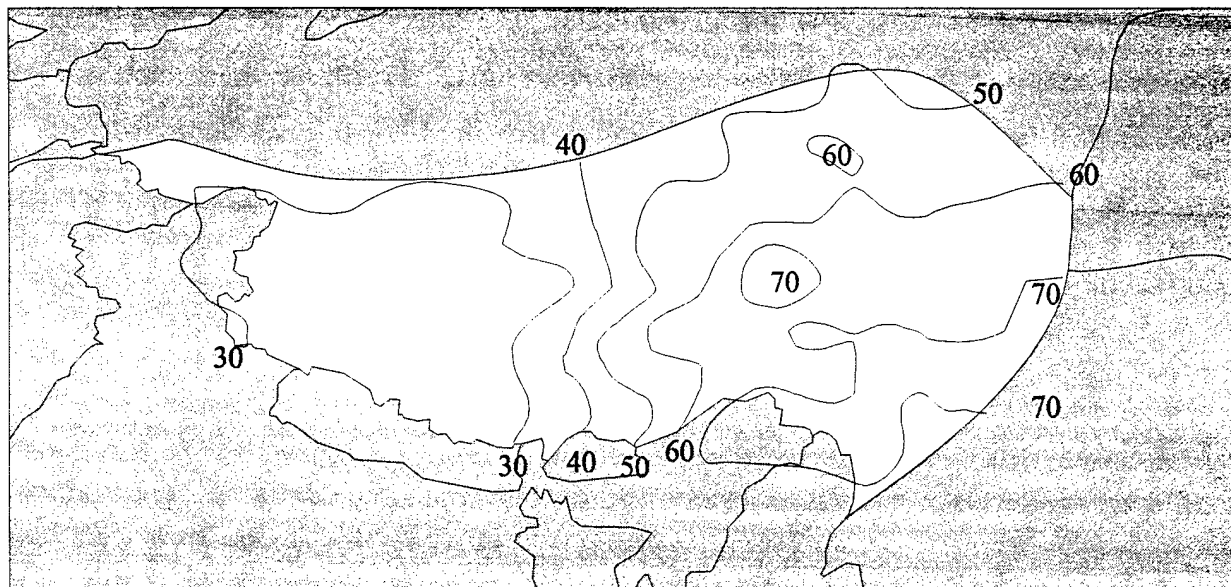


Figure 3-12. April Ceilings. The isopleths represent the frequency of cloud ceilings at all altitudes for local noon.

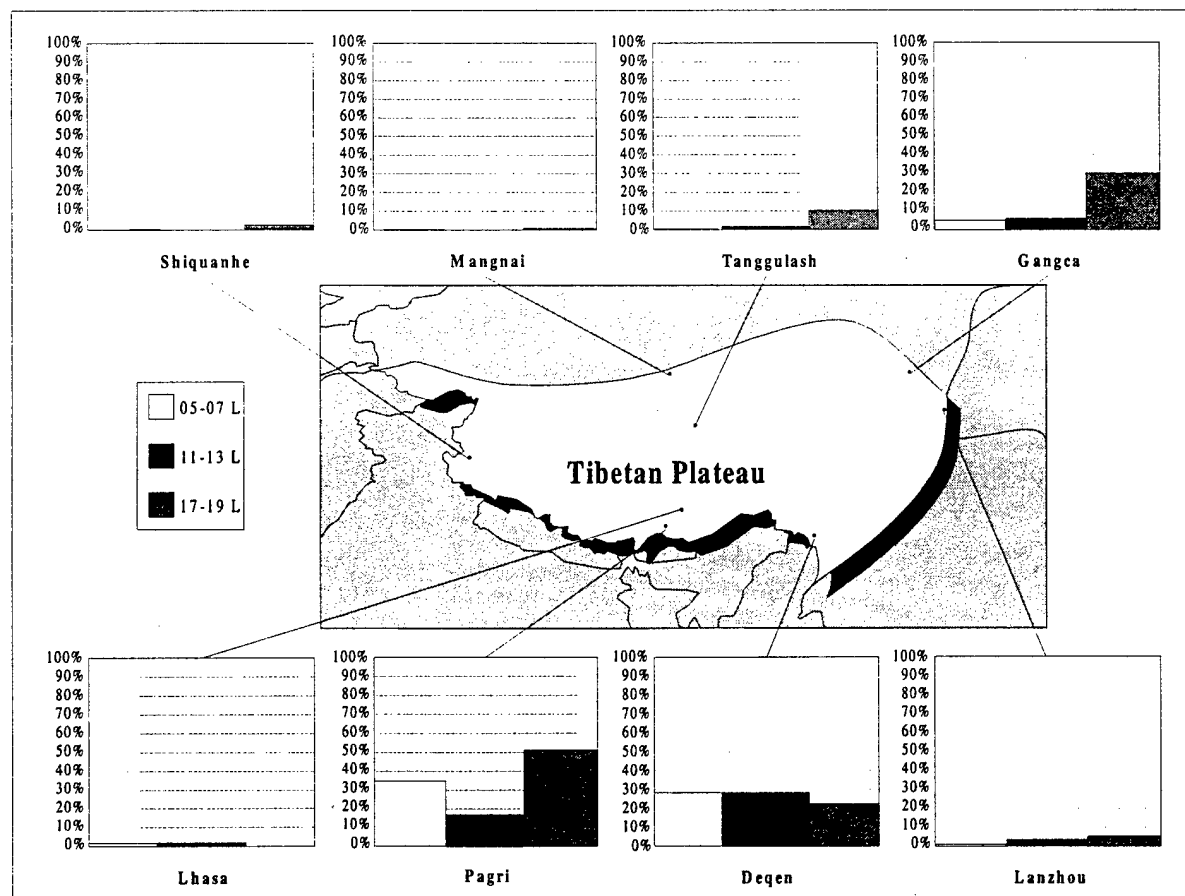


Figure 3-13. April Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Blowing sand and dust occur most often in the vegetation-sparse north where there is little moisture left after the long, dry winter. Higher frequencies of blowing sand can also be expected in the western portion of the southern mountain region with very little chance of fog at most locations. Radiation fog forms along the river valleys at night and in open areas, but dissipates by late morning. Highest fog frequencies occur in the southeast lowland river valleys where more abundant moisture is available.

Southern Mountains Region. Blowing sand occurs 1 to 2 days in the east and increases to 4 to 5 days in the dry west. Fog occurs only 1 to 2 days per month, mostly in the southeast along the

watersheds. Visibility less than 4,800 meters occurs less than 5 percent of the time nearly everywhere except at Deqen where visibility less than 4,800 meters occurs 15 to 20 percent of the time (see Figure 3-14).

Northern Highland and Basins. This is perhaps the worst season for blowing sand because it is the end of the dry season and the summer rains have not yet begun. Near the Qaidam basin, blowing sand occurs 8 to 10 days a month. Fog is rare. Most locations have only 1 day per month. Protected river valleys can get as many as 4 to 5 days with fog. Visibility less than 4,800 meters occurs less than 5 percent of the time; visibility below 4,800 meters occurs 5 to 10 percent of the time along the river valleys of the east.

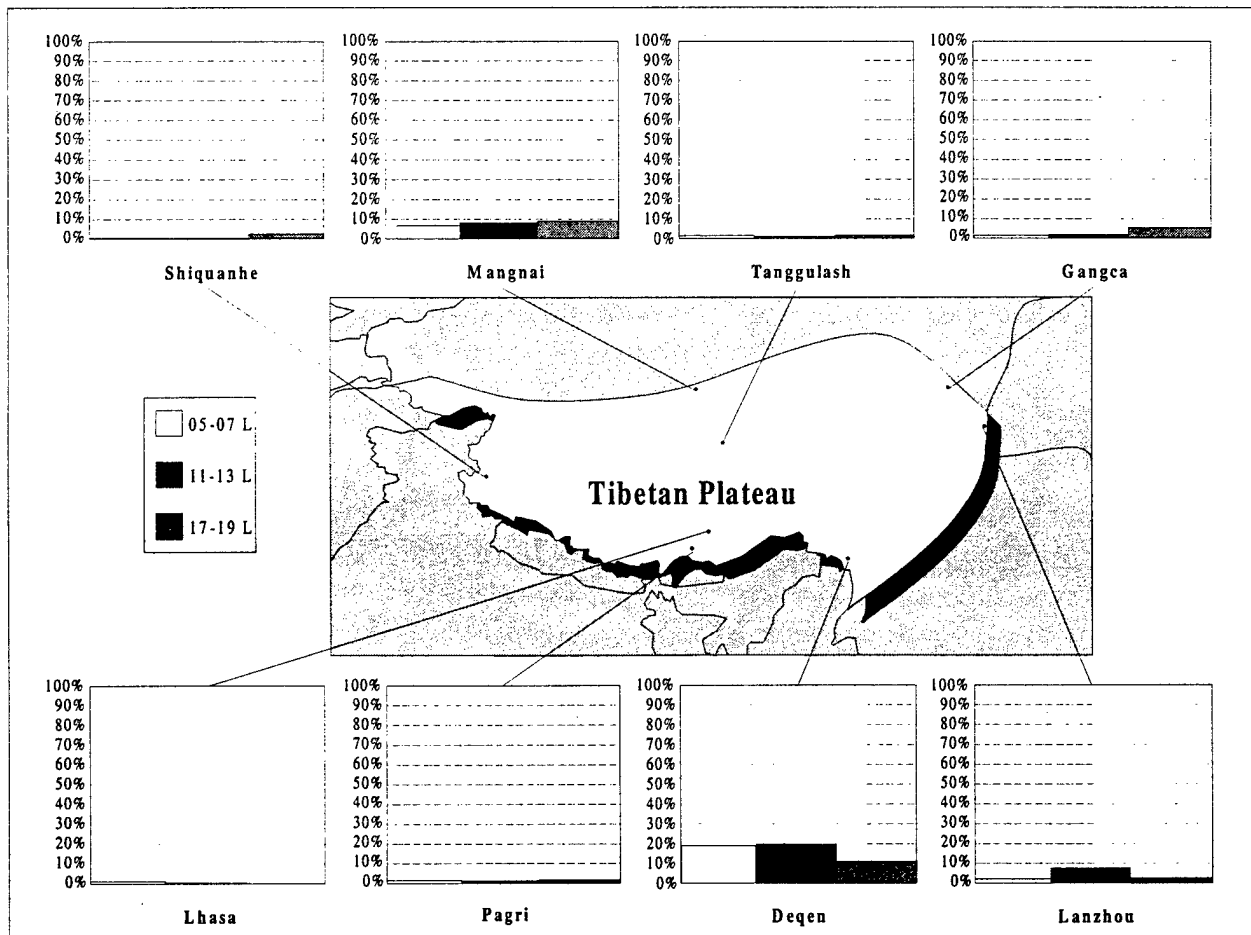


Figure 3-14. April Visibility below 4,800 Meters. The graphs show a breakdown of the percentage of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Surface winds for April are shown in Figure 3-15. Prevailing flow remains westerly at most locations and westerlies continue to dominate the plateau. Wind speeds are still high although they begin to decrease late in the season. Protected valley locations often have calms at night. Boras and foehns can still occur, but they usually occur with less intensity than in winter.

Southern Mountain Region. Southerly winds prevail, especially in the southeastern valleys where the winds are channeled and the southwest monsoon begins its trek northward. Most areas of the western part of the region favor a westerly direction because the upper-level winds affect

surface winds. Lhasa, the exception, has an east-west oriented valley that dominates the area windflow pattern. Average wind speeds continue to be 6 to 15 knots. Speeds occasionally exceed 58 knots when cold air spills down the valleys of the southeast.

Northern Highlands and Basins. The upper-level westerlies affect this region much more than the southern sections because of the many open areas. In the east, even though winds should favor the west, easterly winds are observed because many of the valleys affect the local wind directions. Average winds are 6 to 15 knots with maximum winds of 60 knots possible in the extreme north.

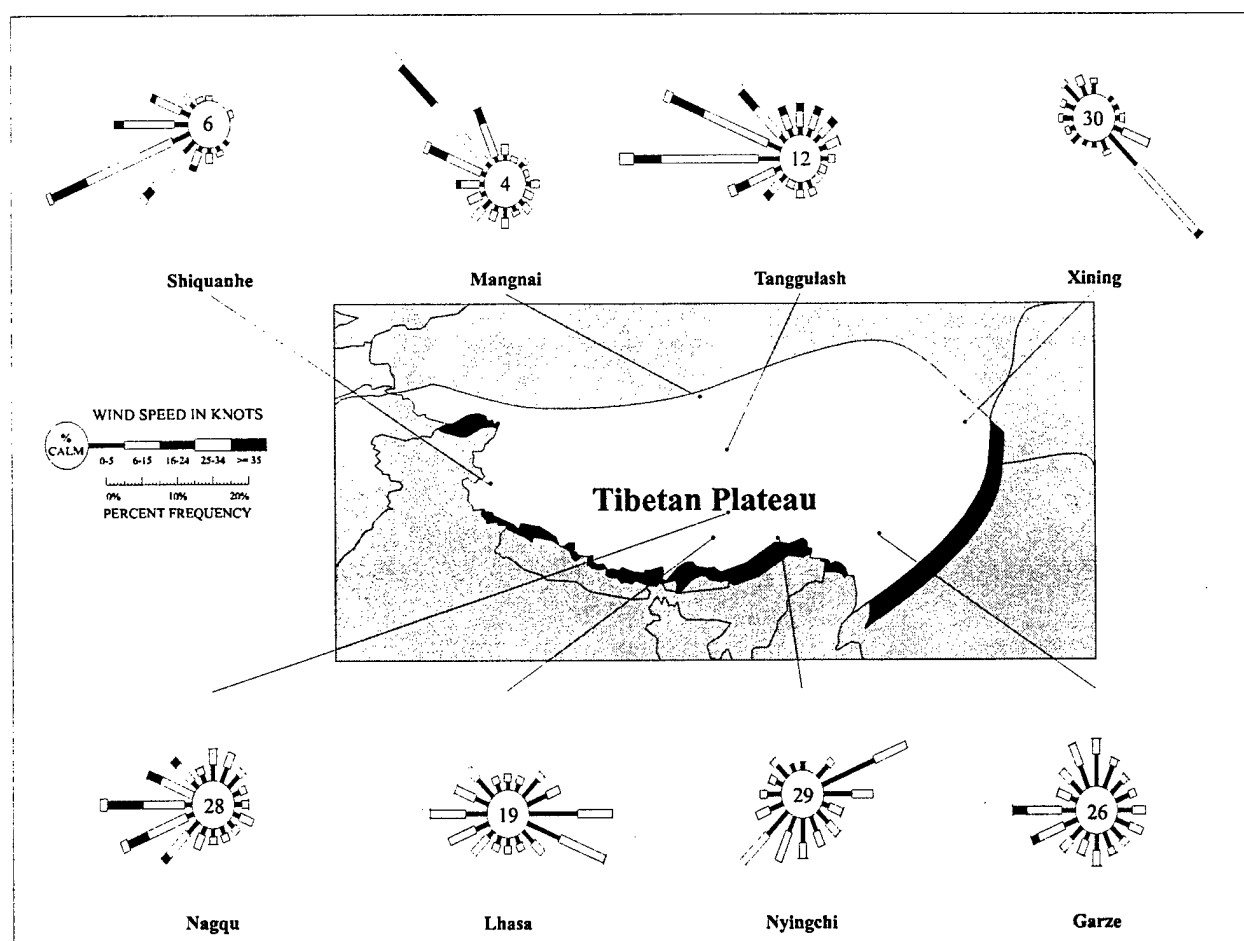


Figure 3-15. April Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Winds Aloft. Winds aloft decrease in speed during spring, but directions generally remain the same as in winter (see Figure 3-16). The subtropical jet that moves north to approximately 30° N increases wind speeds at 300 mb above the southern mountain region. The southerly flow in the southeast at 850 mb and below begins to strengthen as the monsoonal trough moves north. Wudu is on the very eastern section of Tibet. The 850- and 750-mb level wind roses in Figure 3-15 are not representative for areas in Tibet that have higher terrain.

Southern Mountains Region. With the subtropical jet situated in the southern mountain region, winds are from the west. Speeds are 65 knots at 300 mb and 20 knots at the 500-mb level.

Northern Highland and Basins. Winds are a little weaker than in the south. The winds are normally westerly. Speeds average from 55 knots at 300 mb and 15 knots at 500 mb.

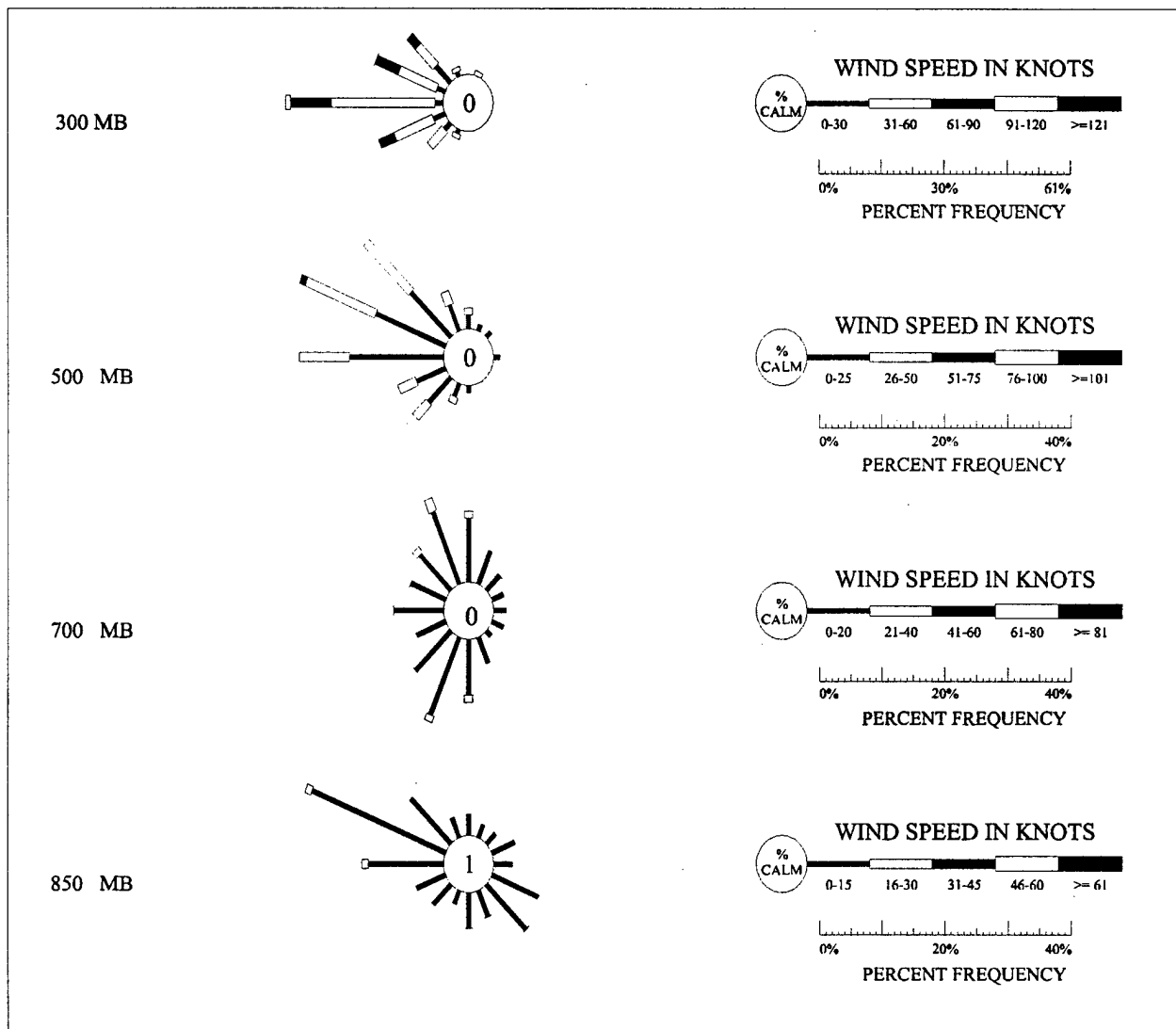


Figure 3-16. April Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Wudu. Note: Each wind rose has a tailored legend.

Precipitation. Precipitation increases from April to May as the pattern shifts from the dry winter to the wet summer pattern (see Figure 3-17). Precipitation amounts increase as thunderstorms begin to develop and increase in intensity in the high mountain areas. Snow continues to fall in the high mountain areas but is usually confined to elevations above 6,600 feet (2,000 meters).

Southern Mountains Region.

Snow. The number of days with snow begins to decrease. Elevations above 9,800 feet (3,000 meters) can still get more than 15 days of snowfall per month. Below 6,600 feet (2,000 meters), most places will only see 1 to 2 days with snow. The eastern portions normally have many more days of snowfall. The number of days and amounts decrease progressively from east to west. Snow depth varies markedly depending mainly on location. Depths range from 18 mm at Deqen, which is located in the east, to as little as 2 mm in the central portions of the region.

Thunderstorms/Rain/Hail. Thunderstorms occur anywhere from 4 to 11 days per month in the southeast to about 1 day in the west. Severe thunderstorms are rare since the plateau has not heated up enough to give the strong uplift needed for formation. During spring, precipitation turns from the stratified type of winter to a showery variety with brief periods of heavy rainfall, especially in the higher elevations above 9,800 feet (3,000 meters). Some locations have rain on more than 20 days per month. Averages appear to range from 15 to 20 days per month in the southeast to as few as 3 days in the west. The southeast has the most precipitation and the highest number of days with rain due to moisture from the southwest monsoon and the many available rivers. Western and central portions receive less precipitation as the Himalayas tend to block the moist southerly winds from the plateau. Precipitation amounts average less than 50 mm in April and less than 100 mm in

May. Hail days usually average 1 to 2 days per month, and the hailstones are usually less than 5 mm in size.

Northern Highland and Basins.

Snow. The northern highlands region is quite different from the southern mountain region. This region experiences an increase in the number of snowfall days, particularly in the southern part of the area because of an increase in moisture. Northern sections are a little different; starting in May, these sections have a gradual decrease in snowfall days. Snowfall day averages range from about 15 to 20 days per month in the south to about 4 days in the north. Snow depths decrease from south to north. Average snow depths are 10 mm in the south and as little as 1 mm in the north. The highest reported snow depth, 18 mm, occurs at Xining, which is located on the western edge of a valley. Upslope conditions and increased moisture from a river to the south combine to produce more precipitation at this location.

Thunderstorms/Rain/Hail. Thunderstorms average about 4 to 5 days per month, although some locations get up to 9 days with thunderstorms, mostly in the later stages of spring. There are quite a few locations in the northern highlands that receive no thunderstorm days. Severe thunderstorms are very infrequent, and hail smaller than 5 mm occurs mostly in the higher elevations. Rain occurs on average 1 to 2 days in April in most areas but increases to between 5 and 10 days (as many as 19) at some isolated sections of the northeast (see Figure 3-18). During spring, the northern highlands receive far less precipitation than the southern mountain region. Precipitation amounts average less than 30 mm in April, but they increase to just under 100 mm in May. A small portion of the northeastern Qinghai Province receives average amounts of less than 30 mm. Most areas seldom receive hail, but the southern portion of the area averages 1 to 2 days with small hail.

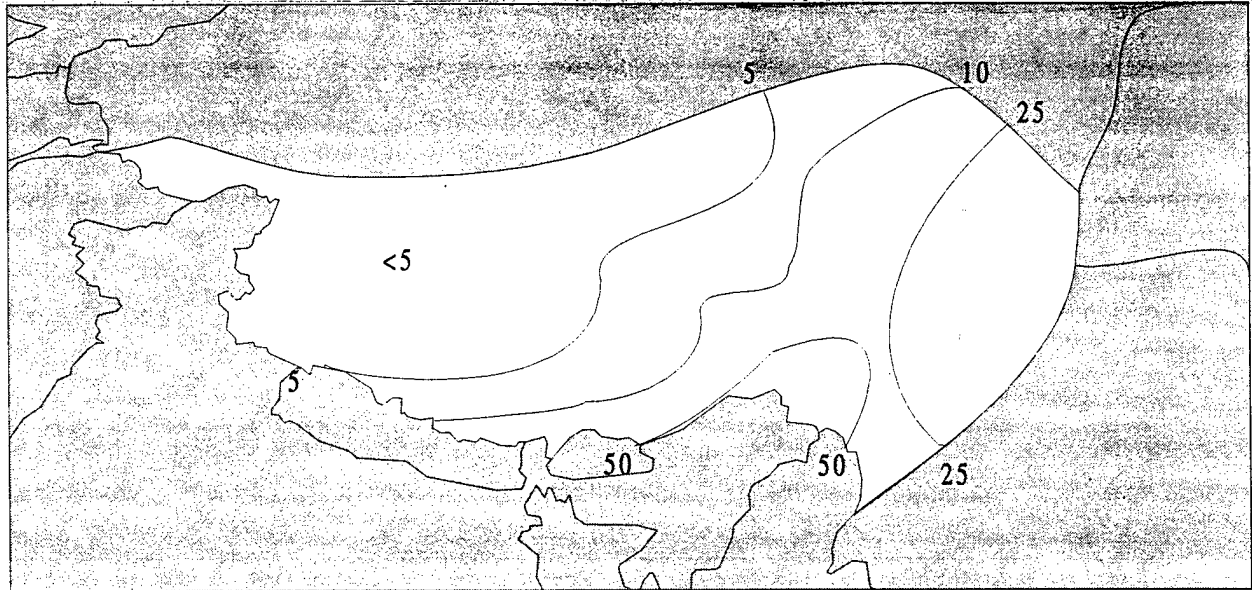


Figure 3-17. April Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

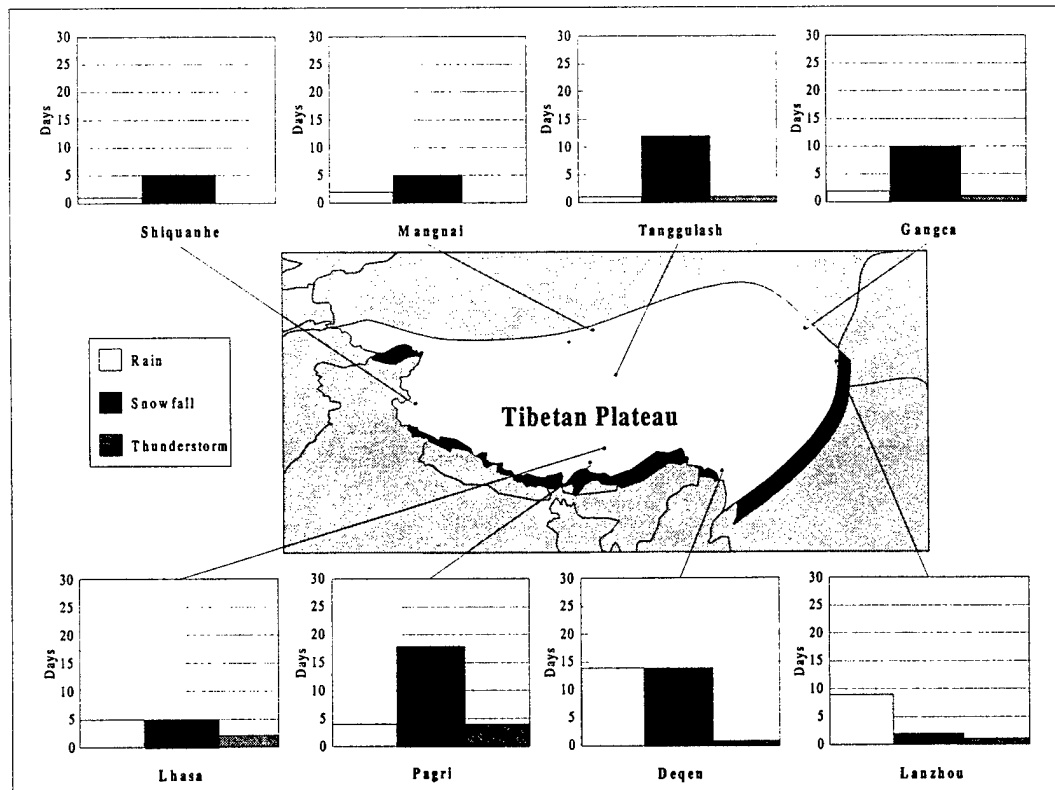


Figure 3-18. April Mean Rain, Snow, and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on average occurrences at scattered locations within the Tibetan Plateau.

Temperature. Temperatures increase steadily over most of the plateau. Warming temperatures arrive later in higher elevations. Snow cover and altitude are the two principle reasons for the cold temperatures. Temperatures at most locations are above 32°F (0°C) during the day, but plummet to below freezing temperatures after sunset (see Figures 3-19 and 3-20).

Southern Mountains Region. Because of terrain, snow cover and elevation temperatures vary widely within the region. Record lows range from 0°F (-18°C) in the west to 21°F (-6°C) in the east where temperatures begin to increase early in the season from the warm, south wind. Record highs range from 64°F (18°C) in the west to 95°F (35°C) in the southeast. Mean temperatures in most locations are above 32°F (0°C) below 13,100 feet (4,000 meters). Above 13,100 feet (4,000 meters), mean minimum temperatures can drop to as low as 18°F (-8°C). Mean maximum temperatures range from 43°F (6°C) in April to 77°F (25°C) in May; mean minimums range between an

average of 18°F (-8°C) in April to 59°F (15°C) in May.

Northern Highland and Basins. Due to its more northerly latitude, this region is colder than the southern mountain region. The extremes in temperatures are mainly contained in the east where the terrain is rugged, there are more open valleys, and is subject to the brief cold blasts from the Siberian air that occasionally occur during spring. Record lows range from -8°F (-22°C) to 32°F (0°C). Record highs range from 55°F (13°C) to 95°F (34°C). Mean temperatures at valley locations below 8,200 feet (2,500 meters) are above 32°F (0°C). Most locations above 8,200 feet (2,500 meters) remain cold. Mean maximum temperatures remain above freezing then drop to subfreezing temperatures at night during April. By May, the mean maximum and minimum temperatures are both above freezing. Mean maximum temperatures range from 37°F (3°C) in April to 72°F (22°C) in May; mean minimums drop to an average of 10°F (-12°C) in April to 52°F (11°C) in May.

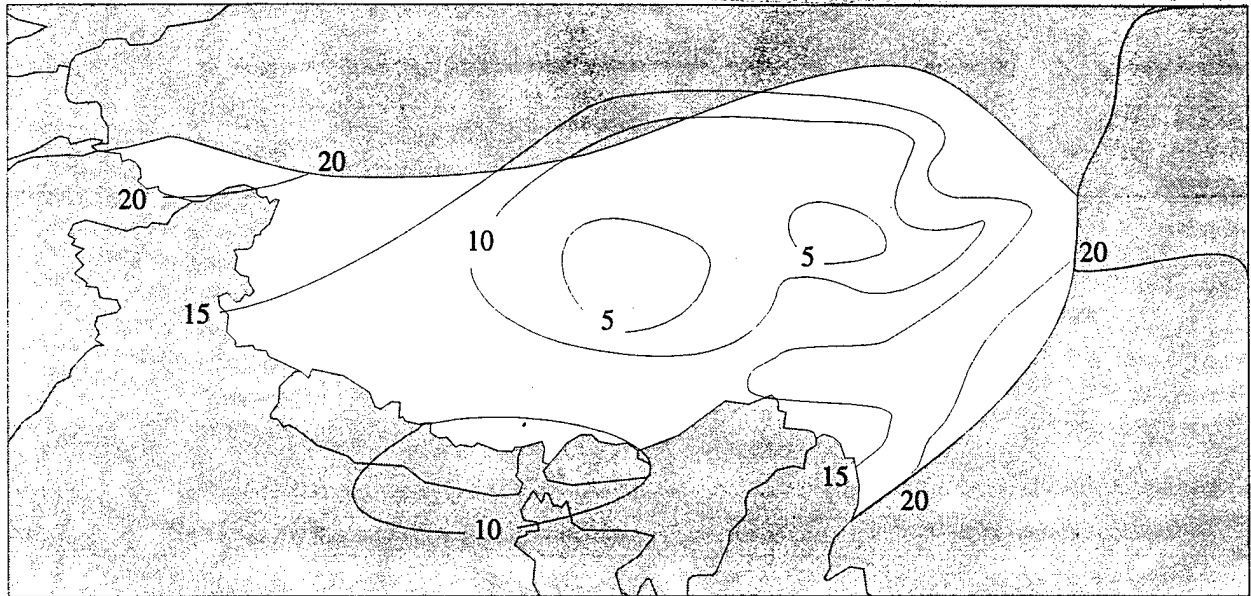


Figure 3-19. April Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for spring.

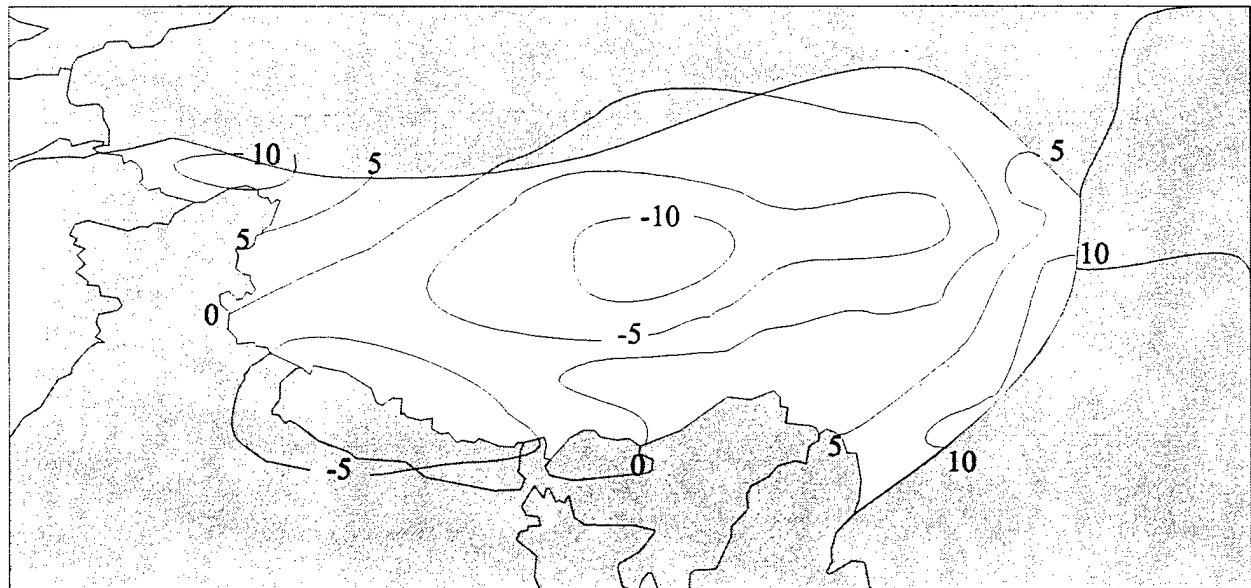


Figure 3-20. April Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average low temperatures for spring.

Hazards.

Turbulence. During winter, the jet stream branches west of the Tibetan Plateau. One branch goes north and the other south. The two branches join together again over Japan. Wind speed increases in eastern Tibet partly because of this downstream confluence, however, the speeds gradually weaken westward. Clear air turbulence can be expected near the tropopause. Heights of the tropopause in winter are 33,000 to 46,000 feet (10 to 14 km). This turbulence can occur nearly anywhere on the plateau, but the most likely area is in the eastern part of the plateau where the winds strengthen.

Even though the jet stream is north and south of the area, wind speeds are west to southwest at 25 to 35 knots at 18,000 to 25,000 feet (5 to 8 km). This creates potential for moderate-to-severe mountain-wave turbulence. The best chance for mountain-wave turbulence is in the winter when westerlies are a little stronger. Most likely, this type of turbulence can be expected below 20,000 feet (6 km) west of 90° E on the lee side (north) of the Great Himalayas, east of the Karakorum Mountains in western Tibet, and over the north-south oriented ranges in southeast parts of the plateau.

Icing. Tops of icing generally extend to 30,000 feet (9 km) MSL. The most severe icing conditions are found in the upper half of tall cumulus clouds

prior to the thunderstorm stage and immediately before rain begins to fall. Mixed icing can be expected during the dissipation stage when clouds flatten into layers of stratocumulus and altocumulus. Under most circumstances, thunderstorms only cover a small portion of the area and are easily circumnavigated, so they pose no threat to aircraft. Clear icing is the most common type of icing found in thunderstorms. Stratus and stratocumulus clouds usually have rime ice. Light-to-moderate mixed (clear and rime) icing is possible with altocumulus. The level where icing would be the heaviest is from 15,000 feet to 25,000 feet (5 to 8 km) MSL.

Hail. Hail occurs occasionally and can pose a problem to not only aircraft, but also to ground operations. In China, small hail is considered less than 5 mm and large hail is greater than or equal to 5 mm. The highest frequency of hail occurs east of 95° E and south of 35° N in the eastern half of the plateau. The most likely areas for hail are over mountains rather than on plains and valleys because the uneven heating and dynamic disturbances that occur over the mountains result in strong convection. More hailstorms are found on windward slopes than leeward slopes and on southern slopes rather than northern slopes. Danger to aircraft can occur over mountains, on windward slopes, and on the southern slopes of mountain ranges.

Trafficability. The Tibetan Plateau is the world's highest plateau. It is surrounded by massive mountains, many of which have permanent snowcaps and glaciers. The plateau is a mixture of high mountains, hills, and intermontane plains and alpine meadows. It has many wide valleys, basins, lakes, and salt flats. Slopes are gentle to moderate on the plains and hills and steep in the mountains. Most of the soils are coarse-to-medium grained with fine soils in basins and salt flats. In some high mountain meadows, highly organic and peat soils overlay permafrost. When dry, movement conditions are fair to good on the plains, the wide valleys, on salt flats, and in most basins. When wet, movement is confined to areas of coarse-grained soils and to established routes. Movement

conditions are poor to unsuitable in most hills and mountains, restricted mainly by steep slopes and rugged terrain. Movement is possible in some broad mountain meadows, especially when they are frozen.

The Sichuan basin is an area in south central China. Within this basin are low mountains, hills, and many streams and terraces. Consisting of mostly fine-grained soils. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. In the dry season, conditions in the hills and plains are poor to good. Conditions depend on local agricultural practices. Movement conditions are unsuitable in flooded rice paddies and in highly terraced areas. During the wet season, conditions are poor to unsuitable in most places.

General Weather. During summer, a large, weak, and diffuse thermal low-pressure system forms from the long hours of sunshine over the huge Asian land mass. The center, normally found over northern India or Pakistan east of the Persian Gulf, brings weak cyclonic circulation over the plateau. The monsoonal trough generally reaches the extreme southeastern portion of the plateau during the first week in June. Clouds thicken and precipitation increases throughout the southern mountain region. Generally, precipitation and cloudiness extend as far north as the southeastern portion of the northern highlands and basins. North of 35° N and west of 90° E moisture decreases rapidly as the warm and moist tropical air mass modifies and takes on more continental characteristics. Troughs in the westerly upper-air flow can produce occasional periods of cloudiness and precipitation east of the Karakoram Mountains through advection of mid-level moisture from the Mediterranean Sea. The thermal low and the rapidly heating plateau

increase temperatures and the potential for heavy showers and thunderstorms.

Occasionally, tropical storms move from the low latitudes into India. The Himalayas block most storms out of the plateau. However, these infrequent storms can thicken clouds and bring scattered showers into the southern mountain region, especially to the lower elevated area of the southeast.

In early summer, prior to the onset of the monsoon over central India, the circulation pattern above and around the Tibetan Plateau consists of winter characteristics. It is possible for wintertime disturbances to dominate the southern mountain region when the upper-tropospheric westerlies are still present. These disturbances can give continuous heavy snows to the higher elevations of the southern mountain region due to the moisture influx from the southern monsoon. The northern highlands can get snow, but it is less likely due to the continental characteristics and dryness of the air mass.

Sky Cover. Summer is the cloudiest season of the year for the Tibetan Plateau (see Figure 3-21). Normally, cloud cover decreases from southeast to northwest. The monsoonal trough slowly migrates northward and channels the moisture needed for the extensive cloudiness through the north-south mountain ranges into the southern mountain region and the extreme eastern sections of the northern highlands. Throughout most of the northern highlands and basins, cloudiness occurs infrequently due to depletion of moisture from the air as it crosses the several mountain ranges. Topography plays a key role in influencing cloud coverage. Windward mountain sides and higher elevations have more cloudiness than the lee sides and lower elevations. Lakes, rivers, and mountains also influence a location's cloud type, amount, and height.

In the southern mountain region, sky cover ranges from more than 80 percent of the time at exposed locations in the southeast to 70 percent of the time north of the Himalayas and along the Brahmaputra River valley. The northern highlands and basins receive cloud cover 50 percent of the time. Cloud cover occurs 70 percent of the time in extreme eastern sections of the region where the monsoonal moisture affects the area.

Southern Mountain Region. Ceiling height and frequency vary greatly with changes in elevation and exposure. Very low ceilings are seldom observed anywhere but on windward slopes. Ceilings less than 3,000 feet occur 10-20 percent of the time in the western section where there is not as much moisture. These ceilings occur 60-70 percent of the time in some locations along the northern slopes of the Himalayas and on exposed slopes of

the southeastern part of the region (see Figure 3-22). Deqen, which is located between the Mekong and Yangtze rivers, has strong nocturnal cloudiness. In July during peak monsoonal flow, Deqen has ceilings less than 3,000 feet nearly 62 percent of the time from sunrise to midmorning. The majority of these ceilings (41 percent) are below 500 feet. Most of the remaining 21 percent of the total (62 percent) consists of ceilings below 3,000 feet but above 1,000 feet. Ceilings below 1,000 feet but above 500 feet occur only 3 percent of the time.

Northern Highlands and Basins. In the extreme northwest, ceilings are rare and usually occur less than 5 percent of the time. In the southeastern part of the region they occur about 10 to 20 percent of the time. The exception is at Gangca (on the north shore of the Quinghai Lake in the Quinghai Province). Gangca has ceilings about 45 percent of the time due to the lake effect and to the afternoon convection that occurs in the daytime heating along the mountains. Averages at most other locations around Gangca are less than 10 percent. Cloud types in the Tibetan highlands vary noticeably by time of day. An abundance of moisture brought in by the monsoonal winds from the south, the orographic effects of the terrain, and the unequal heating of mountain slopes combine to provide good conditions for cumulus development over the southern mountain region, and to a lesser extent over the northern highlands. Stratocumulus and some altocumulus are common during the morning hours. Cumulus and cumulonimbus are common during the afternoon. Most of the cumulus and cumulonimbus dissipate or spread out into a layer of low altocumulus as night approaches.

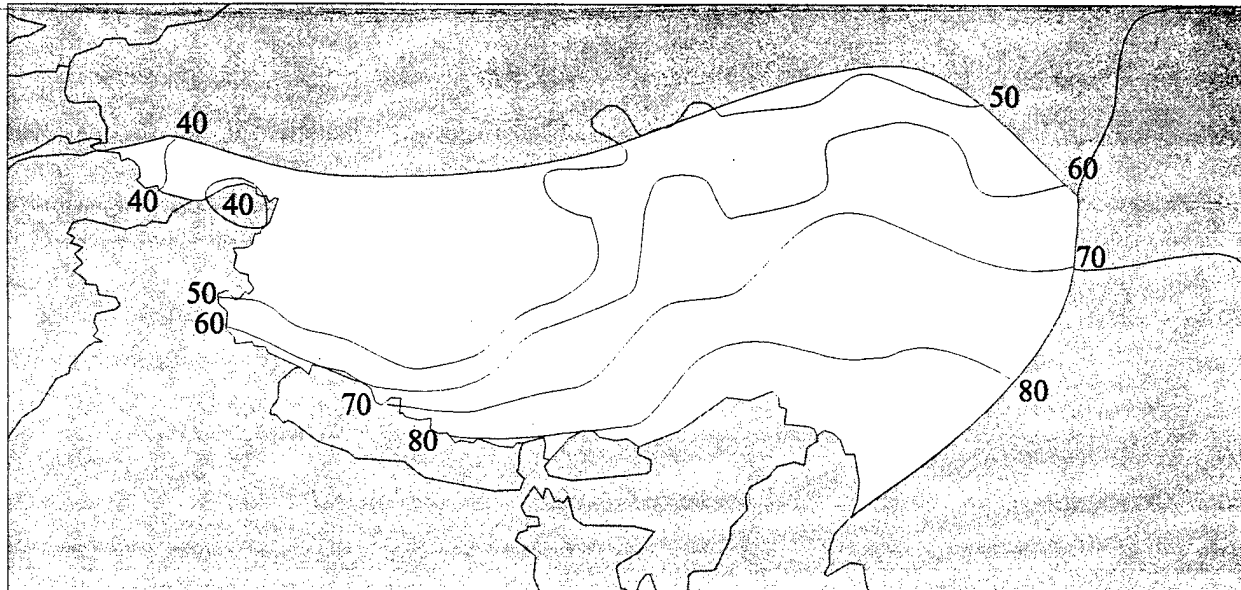


Figure 3-21. July Ceilings. The isopleths represent the frequency of cloud ceilings at all altitudes for local noon.

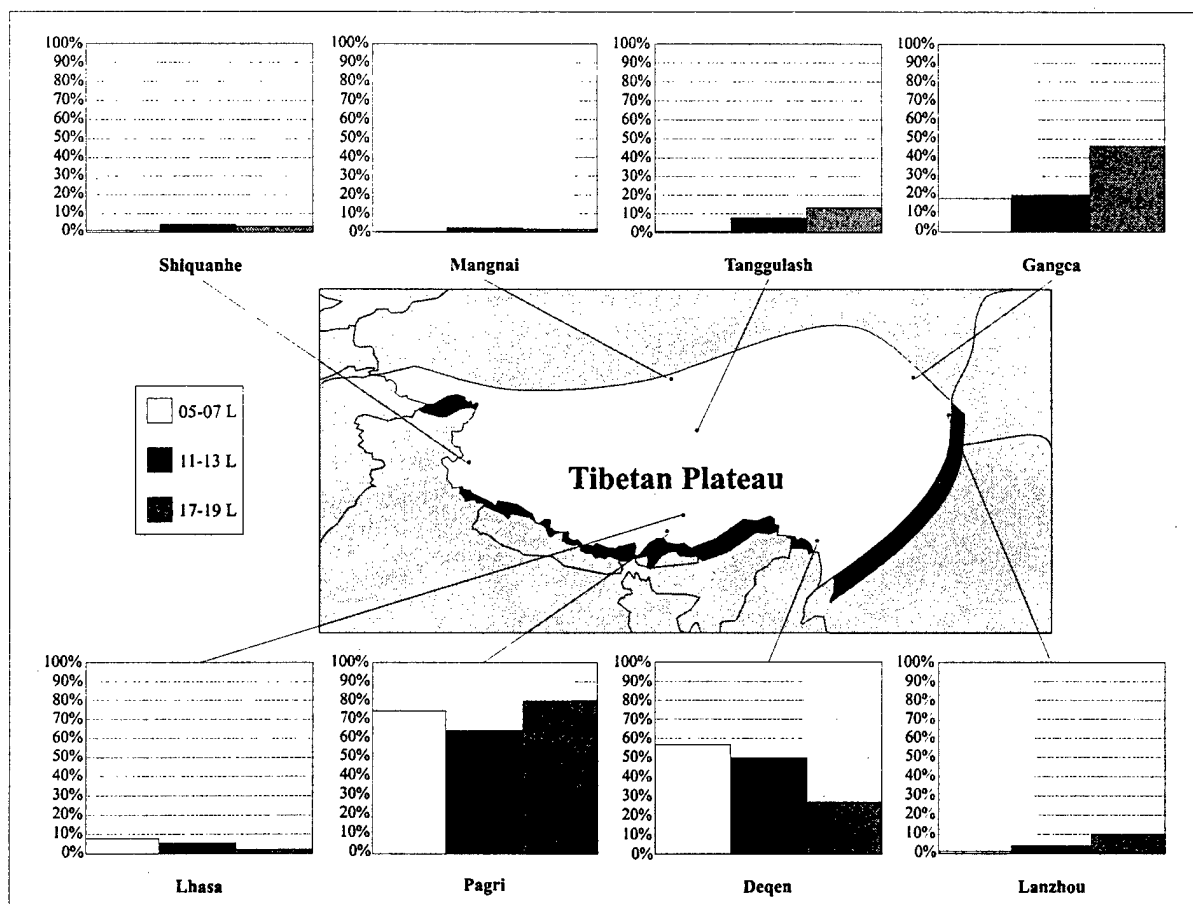


Figure 3-22. July Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. As shown in Figure 3-23, fog rarely forms during the summer except in the higher elevations and along low-lying river valleys. Most fog forms after sunset and usually burns off by midmorning. Blowing dust occurs on occasion in the northern highlands because of the limited moisture and the lack of vegetation, especially near the basins. Blowing dust usually rises during the afternoon and settles in the evening when the winds decrease in intensity.

Southern Mountain Region. Visibility below 4,800 meters occurs less than 5 percent of the time at most locations. Fog can cause problems in and along the river valleys of the southeast, particularly along the Salween, Mekong, and Yangtze rivers. Deqen, because it is located near the Mekong River (the river augments monsoonal moisture), has the highest

frequency of reduced visibility. This location has fog anywhere between 13 and 27 days per month. Visibility less than 4,800 meters occurs 51 percent of the time; less than 800 meters occurs 37 percent of the time. Most other locations in the region report only 1 day per month of fog and visibility below 800 meters is rare.

Northern Highlands and Basins. Visibility below 4,800 meters occurs less than 10 percent of the time at most locations. Blowing dust is more prevalent than fog in this region, especially around the Qaidam Basin where there is a lack of vegetation or precipitation. The region has blowing dust on about 2 to 5 days per month. There is an average of 1 to 2 days of fog per month.

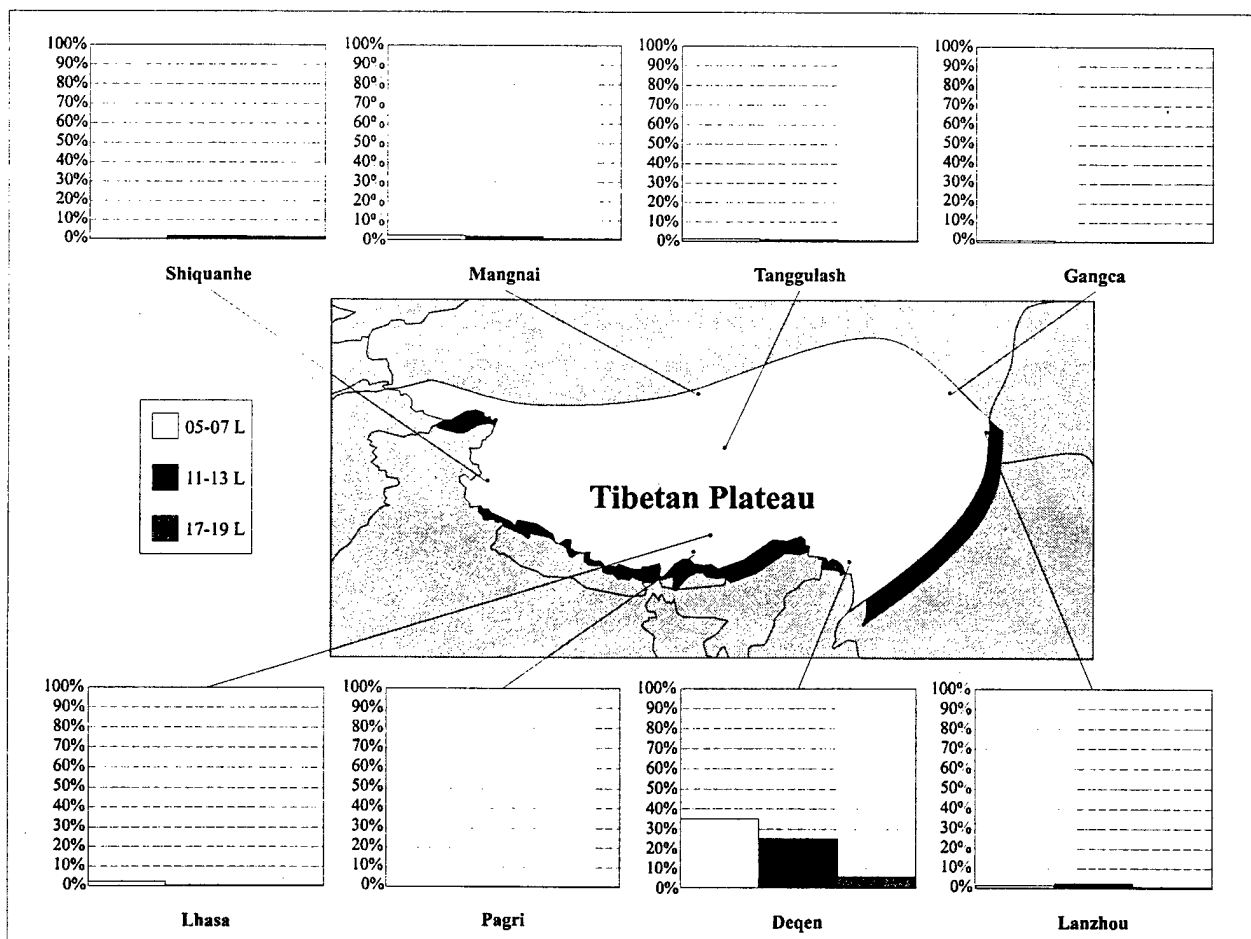


Figure 3-23. July Visibility below 4,800 Meters. The graphs show a breakdown of the percentage of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. A trough cuts through the heart of the plateau. It creates a northeasterly flow pattern in the northern highlands and a southerly pattern in the southern mountain region. This trough is induced by airflow off the Himalaya Mountains to the south and the Kunlun Mountains to the north. Although troughing is evident, overall circulation is weak. Terrain features, such as mountain ranges and valleys, do much to disrupt and distort the overall pattern of both wind speed and direction. In many places, the circulation is complicated and mountain/valley breezes can increase or decrease wind speeds. Mountain winds are the rule rather than the exception and can produce strong, daytime, cooling mountain winds. Also, strong afternoon thunderstorms develop and cause strong and damaging winds. Orientation of mountains and valleys, along with their location with respect to a particular location, influence wind direction more than the large-scale circulation (see Figure 3-24).

Southern Mountain Region. Southerly surface winds dominate under the monsoonal flow that brings frequent cloudiness and precipitation to the eastern half of the region. Westerly winds affect

the western half of the region as a weak branch of the westerlies crosses the Great Himalayan and Karakoram mountains. Wind speeds are generally weak; they average only about 3 to 5 knots in the east and 6 to 15 knots in the west. Extreme wind speeds in excess of 50 knots are possible in the afternoons in association with thunderstorms. Night mountain winds are possible on peaks, slopes, and high passes in all major mountain ranges. The maximum wind speed for the region was 58 knots at Dengqen. Although strong winds are possible at night, the frequency of calm winds in protected valleys in the east is relatively high.

Northern Highlands and Basins. Terrain features influence both wind direction and speed. Wind speeds average 3 to 8 knots with frequent nighttime calm winds. Winds are a little stronger because of the many open valleys and plains that dominate the region. On rare occasions, mountain gusts greater than 40 knots have been observed on some of the higher mountain locations. Gap winds have occurred in the northern highlands. Minhe, located in a deep canyon in the eastern sections of Qinghai Province, recorded an absolute maximum of 107 knots.

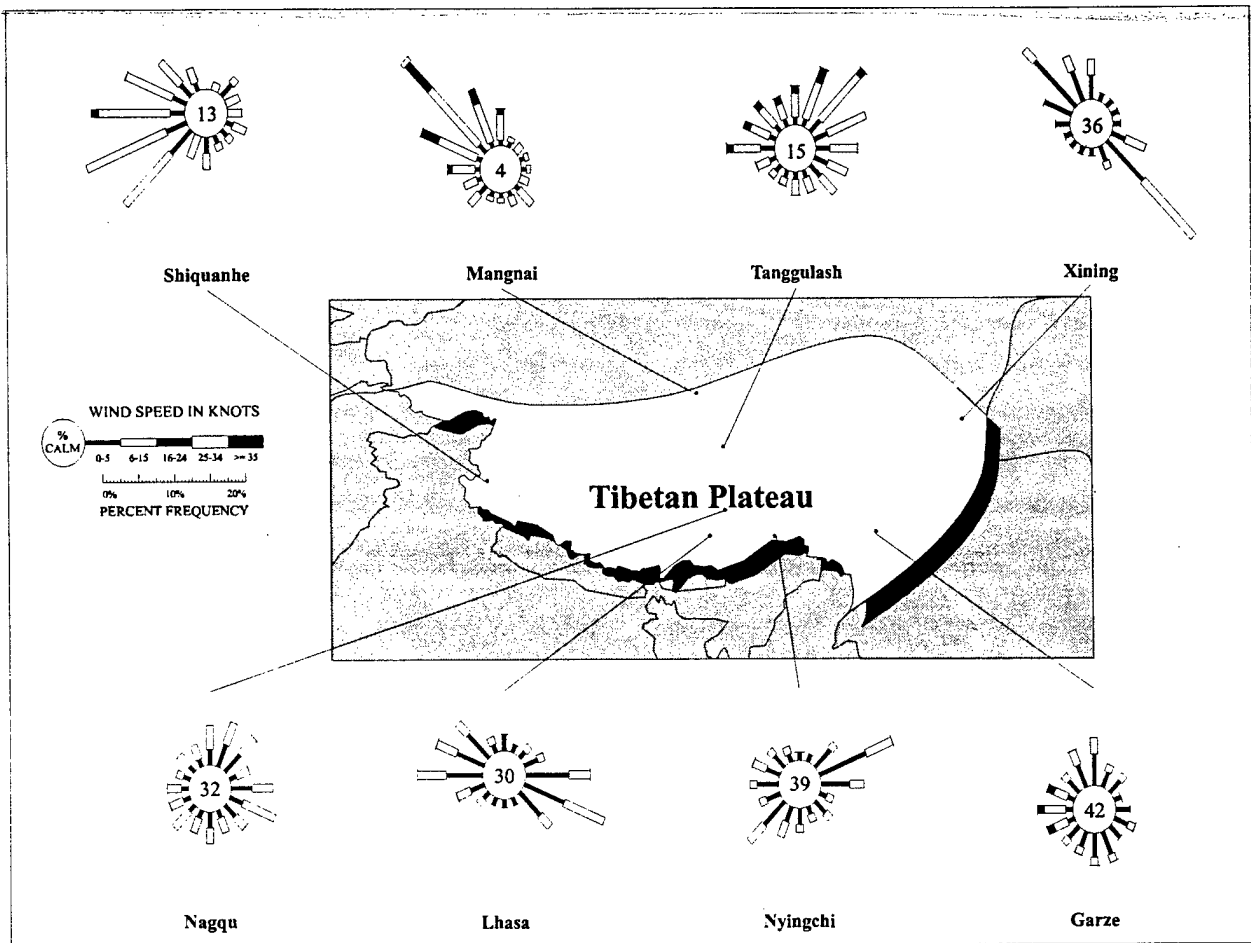


Figure 3-24. July Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Winds Aloft. Elevations throughout the plateau exceed 13,000 feet (4,000 meters). The subtropical jet's axis is located north of the plateau at 200 mb with wind speeds in excess of 50 knots north of 35° N. Wudu is on the very eastern section of Tibet. The 850- and 750-mb level wind roses in Figure 3-25 are not representative for areas in Tibet that have higher terrain.

Southern Mountain Region. Up to 500 mb, average winds are southwesterly at roughly 10 knots. They

become light and variable above 300 mb. Occasionally, when the area is under the influence of the Tibetan high, wind directions are northeast at less than 10 knots.

Northern Highland and Basins. Wind directions are primarily westerly through 100 mb with average speeds of 10 to 15 knots at 500 mb and 55 knots at 200 mb. Above 200 mb, wind speeds decrease to less than 25 knots.

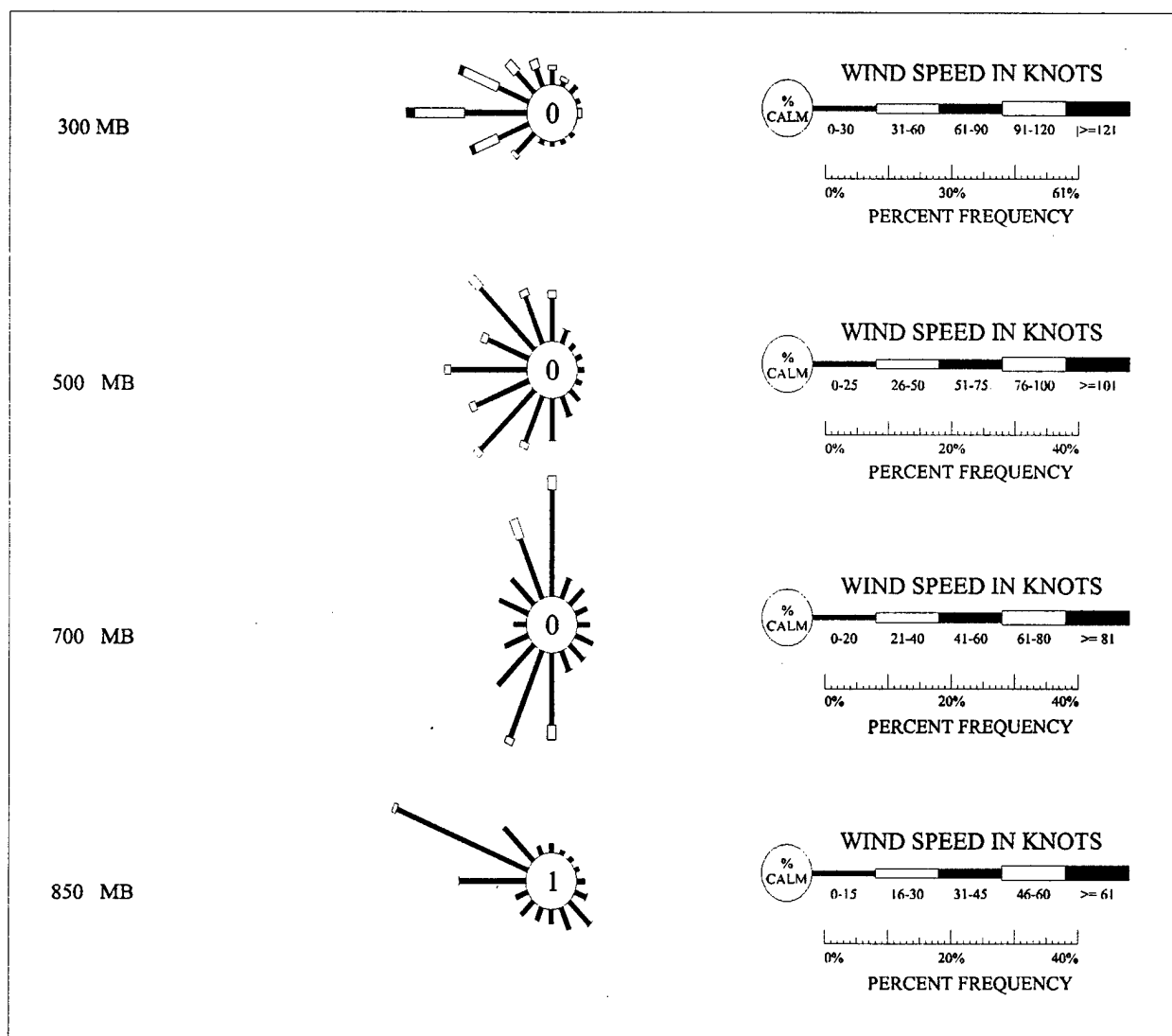


Figure 3-25. July Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Wudu. Note: Each wind rose has a tailored legend.

Precipitation/Thunderstorms. All types of precipitation occur during the summer (see Figure 3-26). The northern highlands contain dry air along with cool temperatures, leading to less precipitation. The southern mountain region receives warm, moist air from the southwest monsoon, which allows for precipitation maximums in the region (see Figure 3-27). During June, snow still occurs in many locations, particularly in higher elevations. Elevation, location, and amount of moisture all influence snowfall accumulations. In summer, elevations are particularly important due to the temperature extremes that occur from the valleys (cool) to the peaks (cold even in the summer). A contributing factor to precipitation type is the drastic diurnal temperature cycle that occurs. During maximum heating, thunderstorms and rain dominate, but as the temperature plummets at night, frozen precipitation can occur. Most snow occurs on the upwind side of mountains where moisture is lifted and saturation is reached. Thunderstorms develop throughout much of Tibet during summer. Increased water vapor from the southwest monsoon, topography, and upper-level troughs embedded in the westerlies enhance convective activity in the southern mountain region and southern portions of the northern highlands. Topography affects the frequency and time of day of thunderstorm occurrence. The number of thunderstorms gradually diminishes from southeast to northwest. Tops of thunderstorms average about 30,000 feet (9 km) to 40,000 feet (12 km), with rare occurrences to 55,000 feet (17 km). Storms are most frequent at mountain locations from early afternoon to late afternoon and evening on the plains and in the valleys. Severe thunderstorms with damaging winds and hail are possible over southern sections of the northern highlands and northern sections of the southern mountain region. This is where continental and maritime air masses collide. Due to the ruggedness of terrain, hail frequency and hail size vary from one location to another.

Southern Mountain Region.

Snow. There are fewer snow days in the southern mountain region, but snowfall is more widespread. The southern mountain region receives a deeper

moisture supply and has access to more water sources such as rivers and lakes. Snowfall occurs 1-2 days per month at nearly every location regardless of elevation. Although snowfall occurs frequently in the summertime, snow accumulations do not occur in this region because of the great temperature extremes and much warmer temperatures that lead to snow melt.

Thunderstorms/Rain/Hail. Convective activity is at a maximum during the summer months, particularly in the southern portions of the region where the most monsoonal moisture is located. Thunderstorms occur 15 days per month in the southern sections as compared to only 2 days per month in western sections of the region. Lhasa and Xigaze, both in south central Tibet along the Brahmaputra River, receive thunderstorms 19 and 20 days per month, respectively. The number of rainfall days is also high along the Brahmaputra River valley, approximately 20 to 25 days per month. Heaviest rainfall occurs in the southeast and decreases in western sections. The extreme southeast receives as much as 150 mm. The western portions get less than 50 mm. Although there is more moisture in this region, hail activity occurs less than in the northern highlands and is much more sporadic. Hail occurs 1 day per month at Dengqen, Tingri, and Shiquanhe.

Northern Highlands and Basins.

Snow. Elevation and temperature play significant a role in snowfall frequency. Snowfall occurs above 13,100 feet (4,000 meters) approximately 3 days per month. Although summer is warm, daytime minimums still hover around freezing, which increases potential for nocturnal snowfall. June has the highest snowfall frequency of any month. Snowfall occurs 10 days per month at many locations above 13,100 feet (4,000 meters). An example of this is Madoi (elevation of 14,019 feet (4,273 meters)). Madoi receives up to 14 days of snowfall a month. Snow days decrease as elevation decreases below 13,100 feet (4,000 meters); at this elevation, snowfall averages 1 to 3 days. Due to arid conditions, the north normally does not receive snowfall. Although snowfall occurs with greater

frequency in summer, snow accumulations are less due to warmer temperatures that cause snow melt.

Thunderstorms/Rain/Hail. Thunderstorms occur 10 to 15 days in the southeast and less than 5 days in the northwest. Less thunderstorms occur in the northwest due to limited moisture. Summer yields more precipitation than any other season. Moisture, orographic effects, and the monsoonal trough combine to give the southern portions of the

northern highlands the greatest amount of precipitation. Precipitation averages 100 mm in the southeast to less than 10 mm in the northwest. Most precipitation occurs from thunderstorms and showers. Hail is more frequent in this area due to the collision of dry continental air and monsoonal moisture. Hail occurs about 1 to 2 days a month with the greatest frequency occurring above 11,500 feet (3,500 meters). The far north, because of the arid conditions, normally does not receive hail.

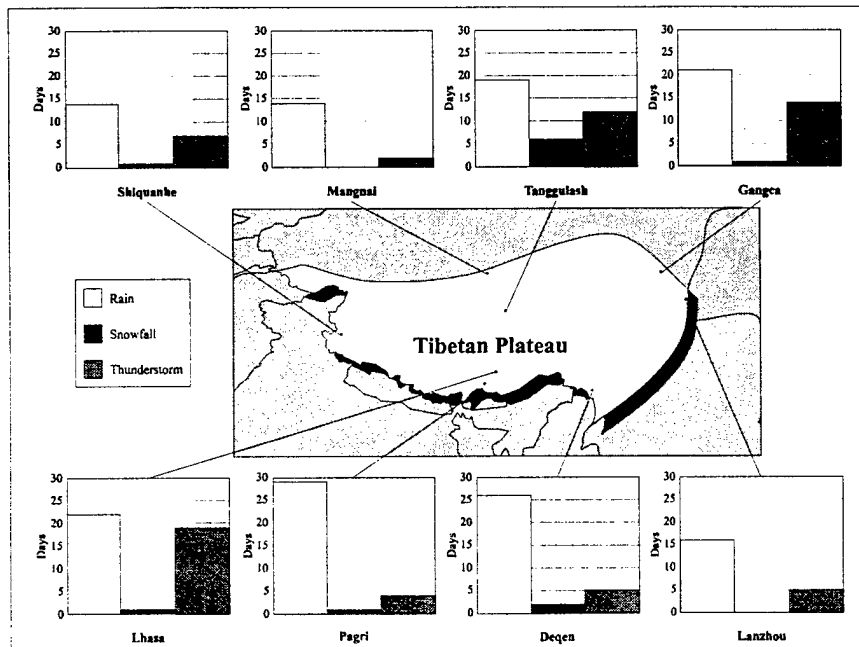


Figure 3-26. July Mean Rain, Snow, and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on monthly average occurrences at scattered locations.

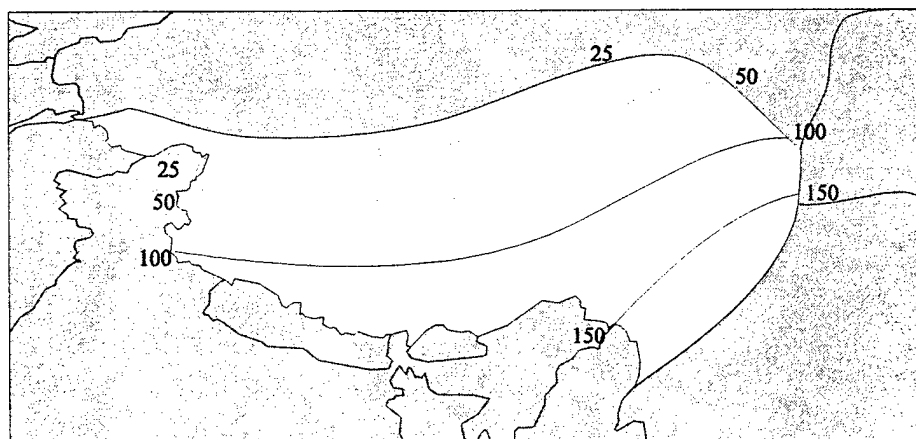


Figure 3-27 July Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

Temperatures. Although the plateau is relatively high in elevation, it acts as a large-scale, elevated heating surface. Comparably high summer temperatures occur there because the effects of the sun's radiation are greater than at lower elevations (see Figure 3-28). The plateau lacks the impurities and moisture in the air of lower elevation stations. This results in high maximum temperatures and radiation loss at night to produce high daytime temperatures and low nocturnal temperatures. Elevations and local mountain and valley breezes play a key role in minimum, maximum, and extreme temperatures. Because of the very high mountains throughout the plateau, there is a large temperature variation from moderate temperatures in the lowland valleys of the southeast to severely cold ones on the high, windswept, snow-covered mountain peaks. Frosts are possible throughout the summer, especially in the north as temperatures drop to near 32°F (0°C) at some locations in the higher elevations (see Figure 3-29). Tuotuohe recorded a mean minimum of 32°F (0°C) during June; many other locations record mean minimum temperatures between 34°F (1°C) and 36°F (2°C).

Southern Mountains Region. Many locations within this region are lower in elevation, particularly

in the southeast. This makes the region warmer than the northern highlands. Mean maximum temperatures range from 59°F (15°C) to 77°F (25°C); mean minimums are from 50°F (10°C) to 59°F (15°C). Wudu, on the very eastern edge of the region, had an extreme maximum of 100°F (38°C) during the month of June. Shiquanhe, in extreme western Tibet, received an absolute minimum temperature of 19°F (-7°C) during the same month. Shiquanhe is more than 9,800 feet (3,000 meters) higher than Wudu.

Northern Highlands and Basins. This area has the greatest diurnal temperature range due to lack of moisture and impurities. Consequently, it has the highest mean maximum and the lowest mean minimum due to radiation gains (days) and losses (nights). Mean maximum temperatures range from 59°F (15°C) to 86°F (30°C); mean minimums drop to an average of 41°F (5°C) to 59°F (15°C). The extreme maximum temperature of 100°F (38°C) was recorded at Lanzhou in June; this location is in a valley at an elevation of 1,518 meters. Tuotuohe, at an elevation of 14,879 feet (4,535 meters), received an extreme minimum temperature of 7°F (-14°C).

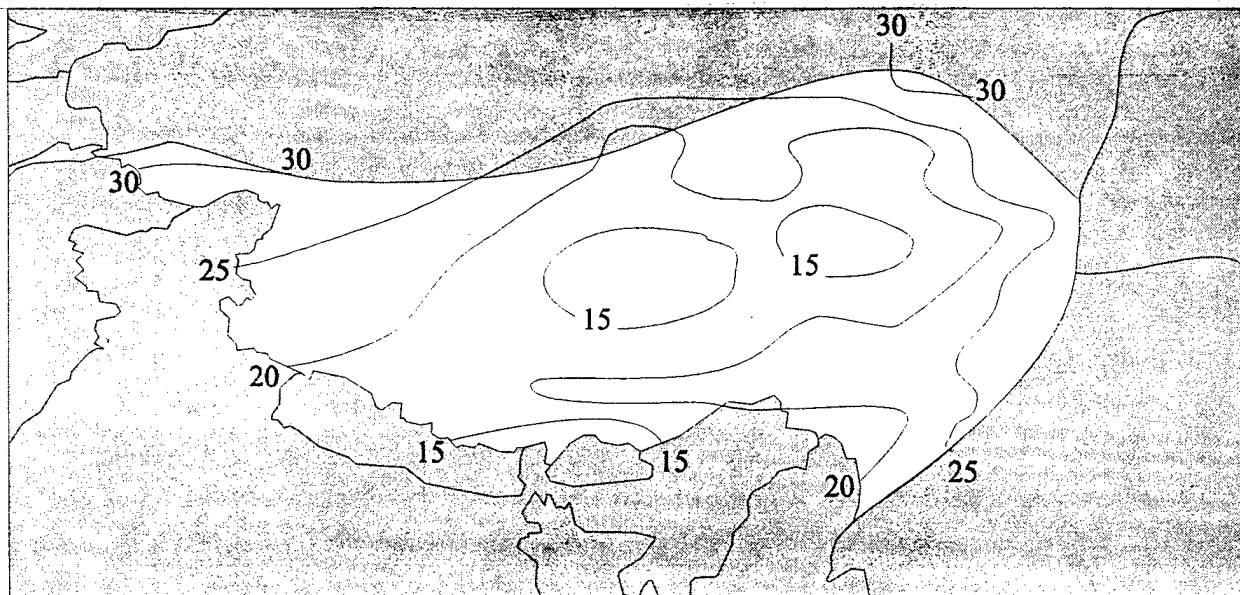


Figure 3-28. July Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for summer.

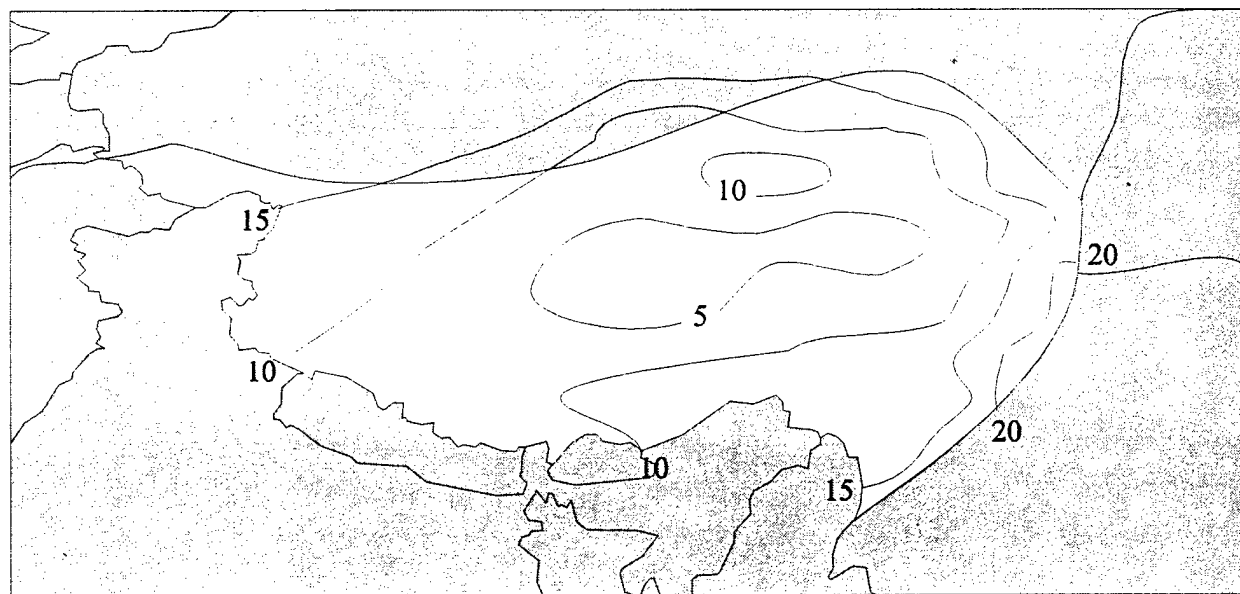


Figure 3-29. July Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average low temperatures for summer.

Hazards.

Turbulence. During summer, clear air turbulence is not normally a problem because the jet stream is located north of the Tibetan Plateau. Clear air turbulence can be expected near the tropopause. Heights of the tropopause are 46,000 to 52,000 feet (14 to 16 km) in the summer. Clear air turbulence can occur nearly anywhere on the plateau, but the most likely area is in the eastern part of the plateau where the winds strengthen.

With the jet stream north of the area, winds are west to southwest at 10 to 15 knots at 18,000 to 25,000 feet (5 to 8 km). Wind speed may occasionally reach 25 to 30 knots and that creates the potential for moderate-to-severe mountain-wave turbulence. Most likely, this type of turbulence can be expected below 20,000 feet (6 km) west of 90° E on the lee side (north) of the Great Himalayas, east of the Karakorum Mountains in western Tibet, and over the north-south oriented ranges in southeast parts of the plateau.

Moderate-to-severe turbulence can be expected in the vicinity of thunderstorms. Since isolated thunderstorms are normally visible, aircraft can usually avoid the hazardous effects of thunderstorms. Caution must be exercised when thunderstorms are obscured by lower clouds.

Light, clear air turbulence on hot summer days is frequent below 5,000 feet (2 km) over flat terrain, but may occur as high as 10,000 feet (3 km) over rough terrain. This turbulence is caused by convective currents (the earth is heated by the hot summer sun and reradiates the heat back into the air).

Icing. During summer, the mean height of the freezing level averages 18,000 to 20,000 feet (5 to

6 km) MSL, which may be only 4,000 to 6,000 feet (1 to 2 km) above most terrain and at the surface on some of the higher mountain peaks. Tops of icing generally extend to 30,000 feet (9 km) MSL. The most severe icing conditions are found in the upper-half of tall cumulus clouds prior to the thunderstorm stage and immediately before rain begins to fall. Mixed icing can be expected in the dissipation stage when clouds flatten into layers of stratocumulus and altocumulus. Under most circumstances, thunderstorms only cover a small portion of the area and are easily circumnavigated so they pose no threat to aircraft. Because most summer icing conditions occur as a result of thunderstorms, clear icing is the most common type. Stratus and stratocumulus clouds normally do not have ice during the summer because they are either below the freezing level, or they are not thick enough. Light-to-moderate mixed (clear and rime) icing is possible with altocumulus. Icing occurs more often in summer than winter; the level where icing would be most probable is from 15,000 feet to 25,000 feet (5 to 8 km) MSL. Cirrus and altostratus are normally made up entirely of ice crystals with little or no water vapor, so icing is negligible.

Hail. Hail can pose a problem to aircraft and to ground operations. In China, small hail is considered less than 5 mm and large hail is greater than or equal to 5 mm. The highest frequency of hail occurs east of 95° E and south of 35° N in the eastern half of the plateau. The most likely areas for hail are over mountains rather than on plains and valleys because the uneven heating and dynamic disturbances that occur over the mountains result in strong convection. More hailstorms are found on windward slopes than on leeward slopes and on southern slopes rather than northern slopes. Danger to aircraft can occur over mountains, on windward slopes, and on the southern slopes of mountain ranges.

Trafficability. The Tibetan Plateau is the world's highest plateau. It is surrounded by massive mountains, many of which have permanent snowcaps and glaciers. The plateau is a mixture of high mountains, hills, and intermontane plains and alpine meadows. It has many wide valleys, basins, lakes, and salt flats. Slopes are gentle to moderate on the plains and hills and steep in the mountains. Most of the soils are coarse-to-medium grained with fine soils in basins and salt flats. In some high mountain meadows, highly organic and peat soils overlay permafrost. When dry, movement conditions are fair to good on the plains and salt flats and in the wide valleys and basins. When wet, movement is confined to areas of coarse-grained soils and to established routes. Movement conditions are poor to unsuitable in most hills and

mountains, restricted mainly by steep slopes and rugged terrain. Movement is possible in some broad mountain meadows, especially when they are frozen.

The Sichuan basin is an area in south central China. Within this basin are low mountains, hills, and many streams and terraces that consist of mostly fine-grained soils. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. In the dry season, conditions in the hills and plains are poor to good. Conditions depend on local agricultural practices. Movement conditions are unsuitable in flooded rice paddies and in highly terraced areas. During the wet season, conditions are poor to unsuitable in most places.

General Weather. The Siberian high begins to strengthen as days grow shorter and nights grow longer. Cold, dry air begins to drop south across eastern China and cause temperatures to drop in the lower elevations and valleys of the eastern portions of the plateau. The Kunlun Mountains, because of their great height, block most cold air out of the plateau. The drier air from the northern highlands and basins area begins to sink south, and the

monsoon trough starts to migrate south in response to the weakening North Pacific high and strengthening Siberian high. By October, all but the extreme southeast lowlands experience a considerable decrease in clouds and precipitation. September often takes on the characteristics of summer with warm weather and some precipitation. October, however, becomes winter-like as precipitation becomes negligible and temperatures plummet.

Sky Cover. As the monsoon trough begins to drop south with its associated moisture and the dry air begins to move in from the northern highlands, cloudiness begins to decrease from north to south (see Figure 3-30). The plateau begins to lose insolation and the cumuliform clouds of September become more stratiform by October. In extreme eastern parts of the area, the general easterly circulation around the Siberian high brings in air masses that are orographically lifted to produce stratiform and nimbostratus clouds along the eastward-facing mountain slopes.

By late October, dry air begins to influence the northern and western sections of the plateau. Cloud cover in the southern mountain region ranges from approximately 80 percent of the time at exposed locations in the extreme eastern portions to 30 percent of the time north of the Himalayas along the Brahmaputra River valley. The northern highlands and basins receive orographically-lifted cloudiness 60 percent of the time in extreme eastern sections of the region to 30 percent of the time in the northwest.

Southern Mountain Region. Ceilings less than 3,000 feet occur from 10 percent of the time in the

western section, where there is not as much moisture, to 60-70 percent in some locations along the northern slopes of the Himalayas and on exposed slopes of the southeastern part of the region. By October, many locations see a dramatic decrease in the amount of low ceilings (see Figure 3-31). Most locations in the west have ceilings less than 3,000 feet 20 percent of the time and 30 percent of the time in the east. Some of the locations in the higher elevations and the extreme southern part of the area continue to experience extensive cloudiness into October.

Northern Highlands and Basins. In the extreme northwest, ceilings less than 3,000 feet are rare and generally occur less than 5 percent of the time. In the southeastern part of the region they occur about 20 to 40 percent of the time.

Thunderstorm and shower activity subsides during fall. Clouds change from cumulus and cumulonimbus to stratus and nimbostratus. Higher elevations of the southern mountain region still receive some cumulus clouds during September. By October, all but the river valleys of the southeast transition to stratiform clouds.

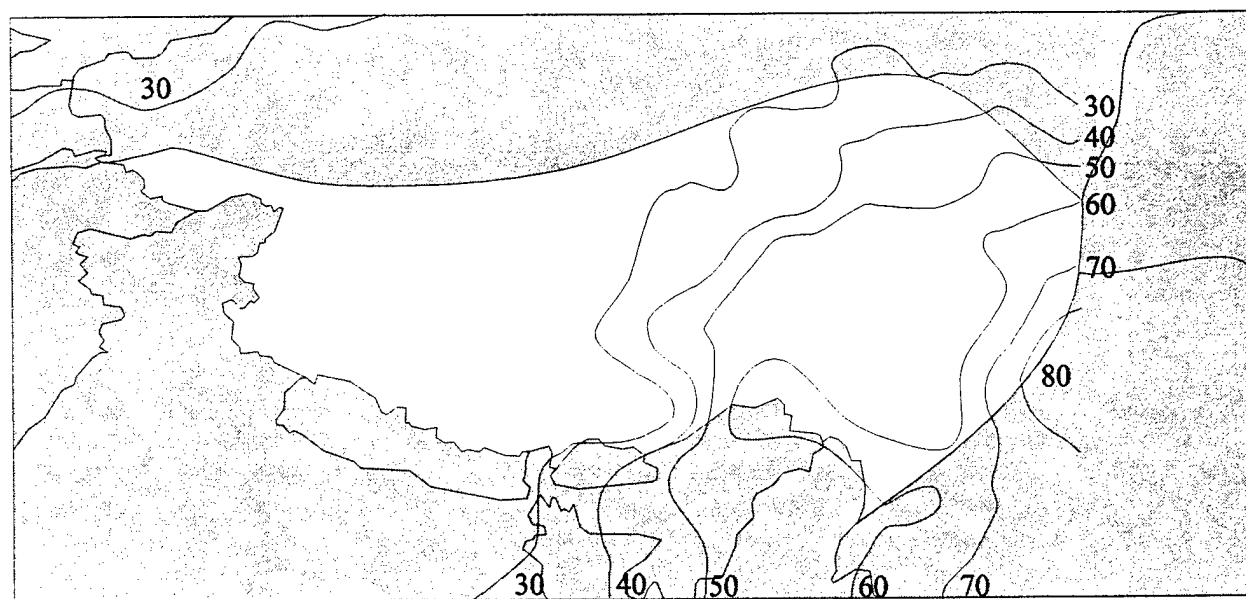


Figure 3-30. October Ceilings. The isopleths represent the frequency of cloud ceilings at all altitudes for local noon.

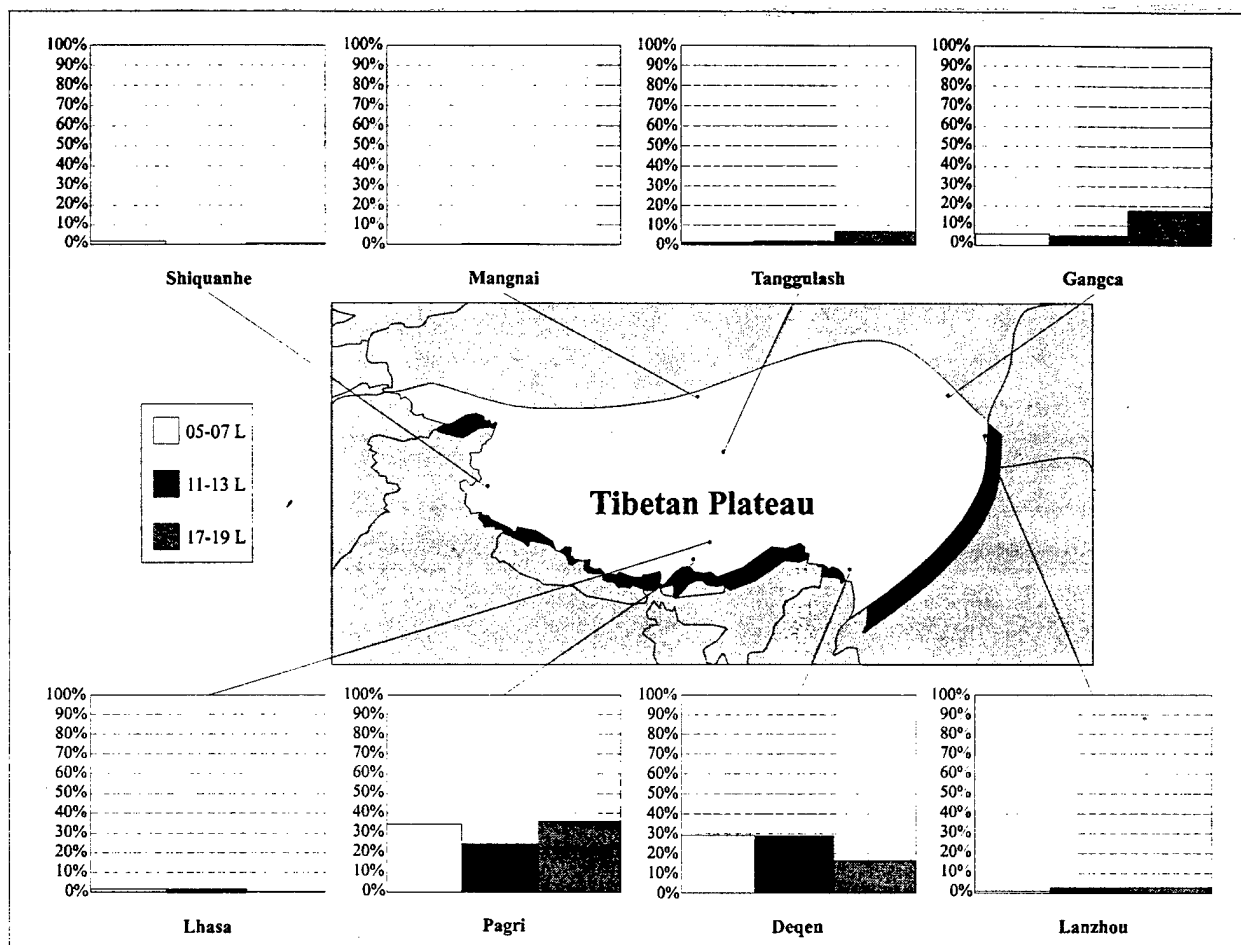


Figure 3-31. October Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Visibility in high, mountainous country is usually excellent because of the drier air and the absence of smoke, dust, and salts more commonly found at lower elevations (see Figure 3-32). The lowest visibility is concentrated in lowland river valleys in the southeastern sections of the southern mountain region. In the western half of the plateau, low visibility is rare.

Southern Mountain Region. Blowing dust and fog is at a minimum. These obstructions reduce visibility to below 4,800 meters less than 5 percent of the time. Radiation fog causes the poorest visibility along the watershed valleys in the southeast where river moisture supplements monsoonal moisture. Generally, monsoonal moisture begins to decrease by October in the region, which decreases the frequency of fog.

Deqen, located along Mekong River, has reduced visibility more than any other location on the plateau. Visibility below 4,800 meters occurs 40 percent of the time in September and tapers down to 20 percent of the time in October. Most of the decreased visibility is from fog and occurs during the morning hours. The region receives fog an average of 1 to 3 days per month; Deqen had the most number of days with 9.

Northern Highlands and Basins. Low visibility due to fog occurs less frequently in this region because of dry air. Blowing dust occurrences decrease in fall to only 1 to 2 days per month. Dust restricts visibility, but not below 4,800 meters. Fog occurs on 1 to 2 days per month and visibility below 4,800 meters occurs less than 5 percent of the time.

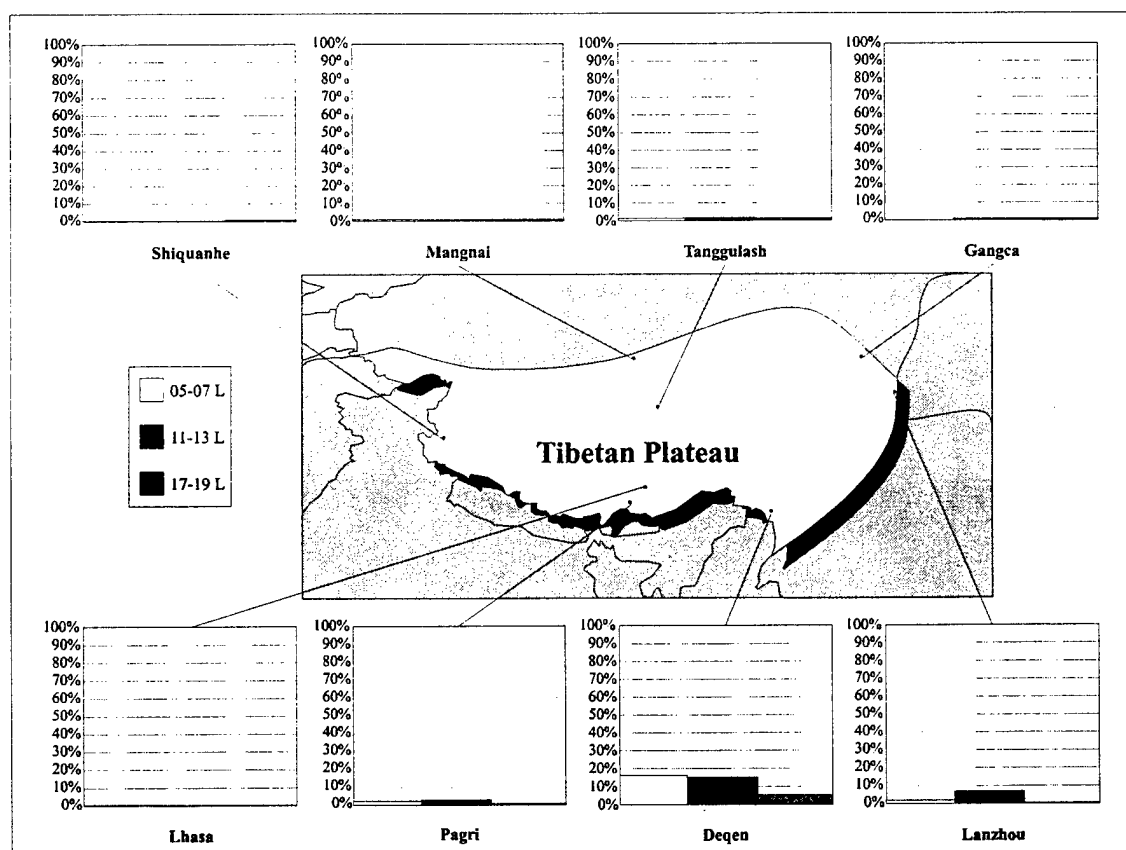


Figure 3-32. October Visibility below 4,800 Meters. The graphs show a breakdown of the percentage of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. As the jet stream strengthens and migrates south, stronger winds dominate the plateau (see Figure 3-33). Most of Tibet is located at or near the 500-mb level, so surface winds are influenced heavily by the upper-level westerly flow. Even though wind flow is predominately westerly, mountain and valley breezes continue to dominate the region. These breezes affect local winds either by offsetting or by enhancing large-scale circulation patterns. Diurnal characteristics, and to a lesser extent topography, continue to play roles in local wind directions and speeds. Winds are normally strongest in the afternoon and the early evening. Later, winds decrease to become very light or calm during the night. As in summer, wind directions are affected by terrain.

Southern Mountain Region. Wind direction gradually changes from southerly in early September to westerly by late October throughout the region as the jet stream strengthens. Average wind speeds are approximately 3 to 5 knots in eastern portions and increase to 6 to 15 knots in western portions. Many locations are protected by mountains, which explains the high percentage of

night calms. Calms occur 40 to 50 percent of the time. Strong winds are rare in valley locations; however, at higher elevations on mountain slopes, near mountain tops, and in passes strong winds occur frequently. Thunderstorm activity subsides drastically by October so the likelihood of convective gusty winds is low. As the plateau begins to cool, local winds strengthen and boras or foehn winds become more common. Lijiang, in extreme southern portion of the region, recorded maximum winds of 56 knots.

Northern Highlands and Basins. The northern highlands winds are westerly throughout fall. The stronger jet stream located over this region causes stronger winds and fewer local circulations than in the southern mountain region. Wind speeds across the region average 6 to 15 knots; calm winds occur 10 percent of the time in northwestern sections and 30 to 50 percent of the time in eastern sections, respectively. Strong winds occur infrequently, but occasionally wind speeds in excess of 40 to 50 knots occur in some of the eastern valleys. Lenghu, on the northern edge of the Qinghai Province, received a maximum gust of 60 knots during September.

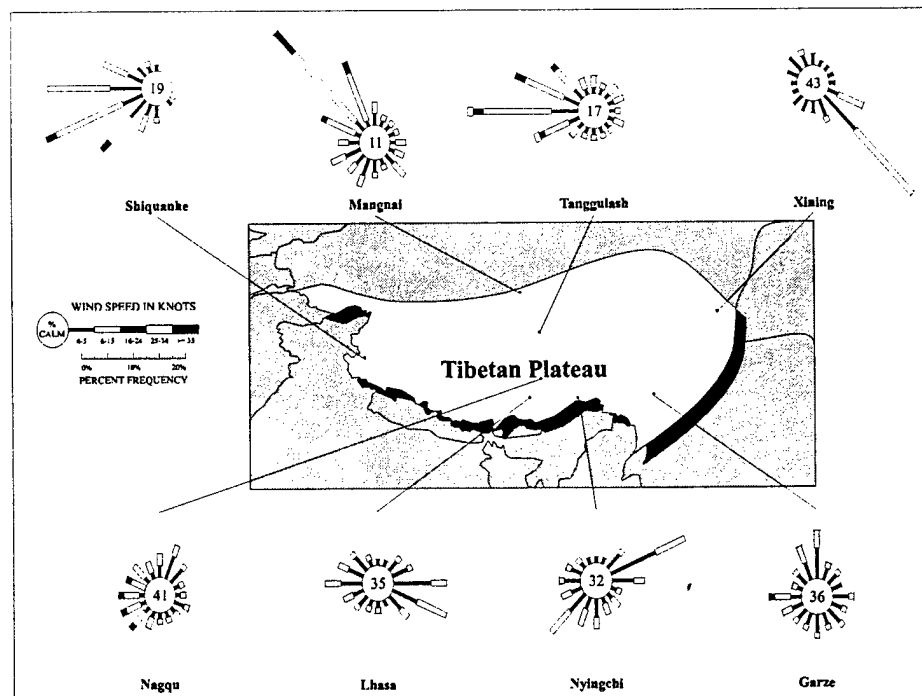


Figure 3-33. October Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Winds Aloft. The subtropical jet begins to migrate south with the axis across the Kunlun Mountains at 200 mb. This produces strong winds in the northern highlands. Winds throughout both regions are from the west. Wudu is on the very eastern section of Tibet. The 850- and 750-mb level wind roses in Figure 3-34 are not representative for areas in Tibet that have higher terrain.

Northern Highland and Basins. West winds dominate the region up through 300 mb with speeds from 15 to 20 knots at 500 mb to 50 to 60 knots at 300 mb.

Southern Mountain Region. Westerly winds, although weaker, prevail from 10 to 15 knots at 500 mb and 30 to 40 knots at 300 mb.

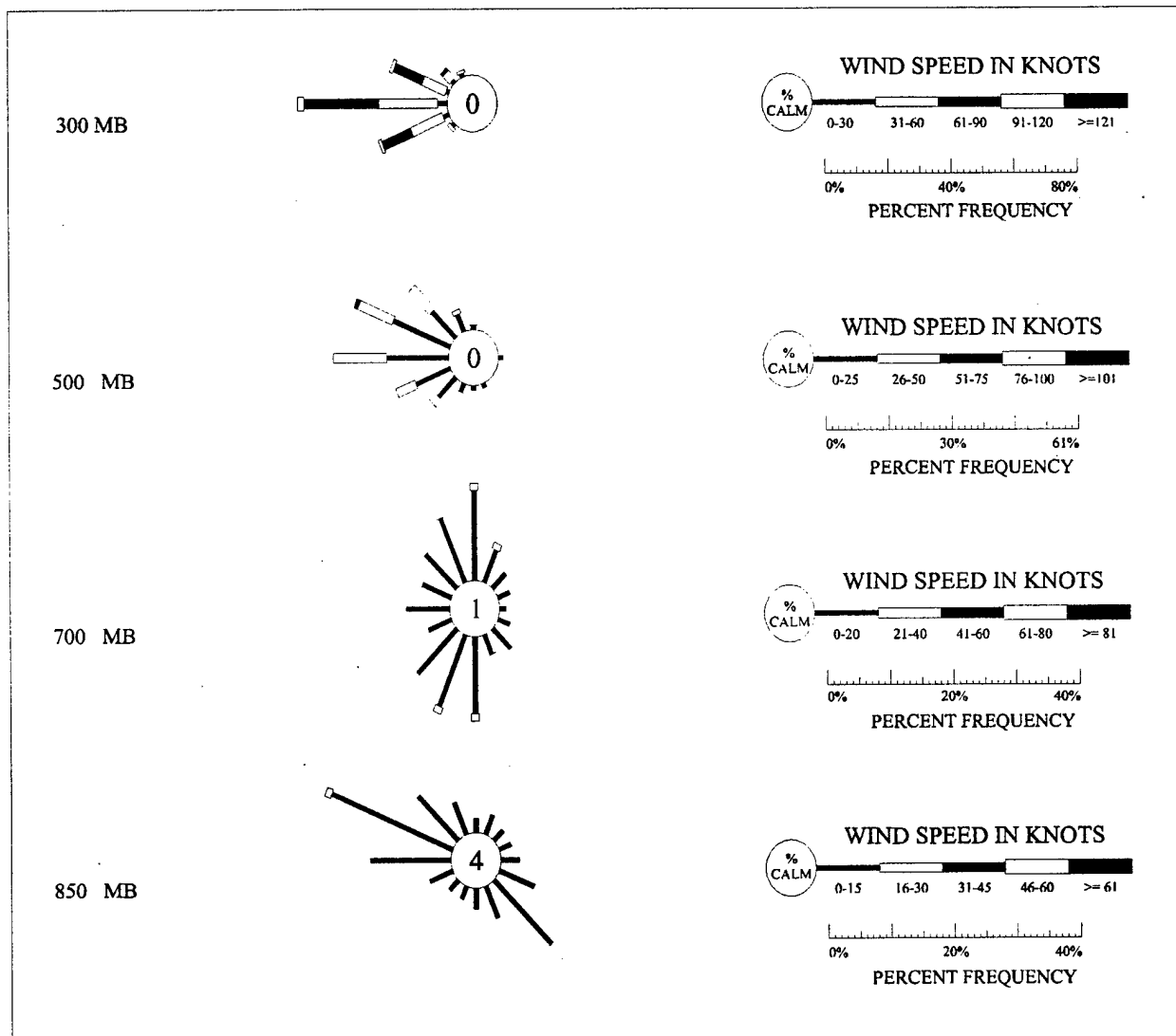


Figure 3-34. October Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Wudu. Note: Each wind rose has a tailored legend.

Precipitation/Thunderstorms. Fall, like summer, has a mixture of precipitation, anything from rain and thunderstorms to snow. The monsoon trough treks south, and moisture and cloudiness soon follow. Precipitation amounts decrease dramatically from the northwestern to the southeastern portion of the plateau. Daylight hours slowly get shorter and the nights get longer, leading to lower temperatures. Early in the season, thunderstorm and rain days begin to decrease and snow days begin to increase. The number of thunderstorms gradually diminishes as the warm temperatures and moisture begin to subside. Tops of thunderstorms average about 30,000 feet (9,100 meters). Storms are most frequent at mountain locations from early afternoon to late afternoon and evening on the plains and in the valleys. Severe thunderstorms become less likely and very sporadic, but small hail of less than 5 mm is still possible. Precipitation amounts decrease from a monthly average of 200 mm in September to 100 mm in October (see Figure 3-35). Most precipitation is likely to be rain during early fall, but snowfall days begin to increase by late October (see Figure 3-36). Dry, northern air begins to make its way into the area, and even though snowfall days increase, relatively meager precipitation amounts occur.

Southern Mountain Region.

Snow. Snow occurs about 1 day per month in western sections and 3 days per month in eastern portions. The region begins to see an increase in snow days during October as the monsoonal moisture decreases and the freezing level lowers. A maximum of 5 snow days occurs along the higher eastern elevations. Accumulations are low in September; however, they are higher in October when snow depths begin to increase to measurable proportions. Snow depths average about 4 cm throughout the region. Deqen has snow depths of 23 cm, the greatest snow depths of anywhere on the plateau, due to the moisture available from monsoonal flow and the Mekong River.

Thunderstorms/Rain/Hail. Many locations have thunderstorms in September, particularly in the southeast and along the north slopes of the

Himalayas. Few, if any, thunderstorms occur west of 80° E because of the dryness of the air mass. Most thunderstorms and showers are orographically induced and occur on the upwind side of mountains. Thunderstorms occur 7 days per month in September and decrease to only 2 days during October. The highest frequencies of thunderstorms occur in and along river valleys and lakes where there is moisture. A favored location is along the Brahmaputra River and the north-south oriented rivers of the southeast. Rain occurs about 19 days per month in September and 11 days per month in October. Heaviest precipitation occurs in the southeast and decreases in western sections. The extreme southeast receives as much as 100 mm and western portions of the region get less than 30 mm. In the west, the dry, continental climate continues to dominate; only 3 days of recorded precipitation occur at Shiquanhe. Hail becomes very rare because of the lowering freezing level and averages only 1 day per month at 3 or 4 locations in the northeast sections of the region.

Northern Highlands and Basins.

Snow. Fall is the transition from the high precipitation months of summer to the dry months of winter. The southeastern portions of the northern highlands and basins are more likely to receive the most snowfall; this is because of the high elevations and the amount of moisture still available. Early in September, snowfall occurs 5 days per month and increases to approximately 8 days per month in October.

Darlag and Madoi receive an abundance of snowfall; they average 15 days with snow per month. Both stations are high mountain locations in the southern Qinghai Province. Snow depths range from about 4 cm in the north to 17 cm in the Bayan Har and Nyainqentanglha mountains in the southern sections of the region. Most areas do not receive significant accumulations until October.

Thunderstorms/Rain/Hail. During the early part of fall, temperatures and moisture are much like those of summer, so rain and thunderstorm occurrences remain high. The southern slopes of the mountains

in the Quinghai Province and the northeastern ranges of the Xizang Province receive the highest number of days and highest amounts of precipitation. Northern slopes receive the least amount of precipitation because of the downslope conditions that exist on the lee side of mountains. Precipitation gradually decreases north and west from these mountains. During October, the monsoonal trough begins its southward movement which cuts off moisture from the plateau. This drastically decreases the amount of precipitation and allows for drier conditions in the region. Number of days and

precipitation amounts vary because of the local topographic affects. Rain days average from 10 to 20 in the mountains of the south to less than 10 days in the northwest during September. Rain days decrease to less than 10 days everywhere by October. Many areas have less than 5 days of thunderstorms through most of fall. Maximum days and amounts of precipitation and thunderstorms occur from Nagqu to Lanzhou. Maximum precipitation amounts range from 100 mm in the southeast to less than 30 mm in the northwest.

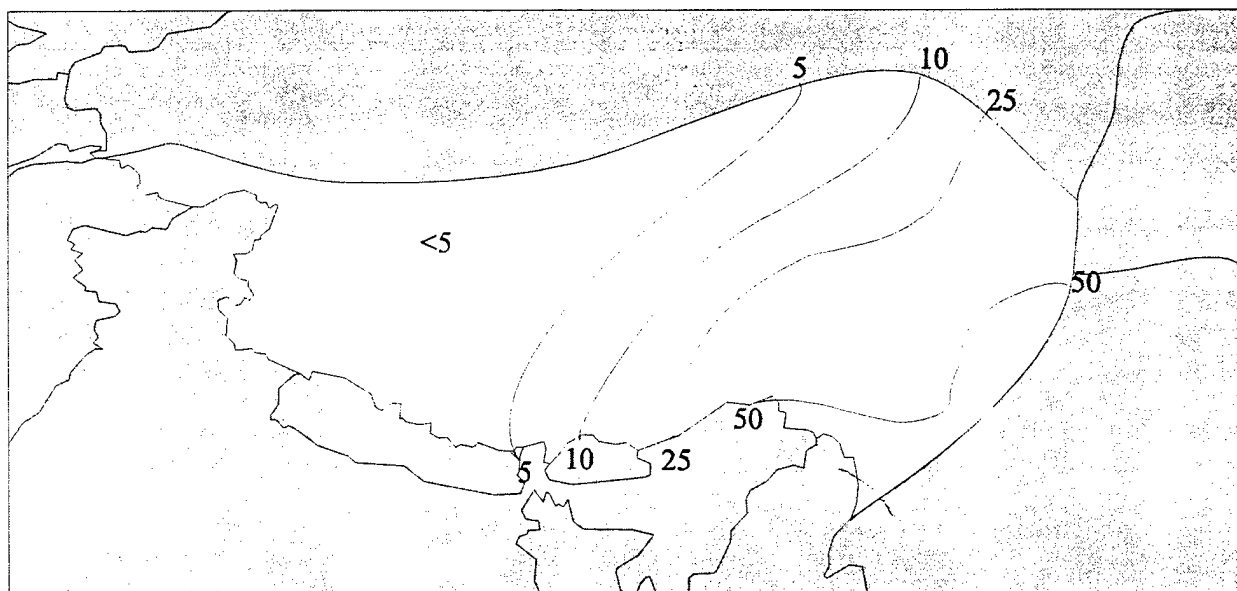


Figure 3-35. October Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

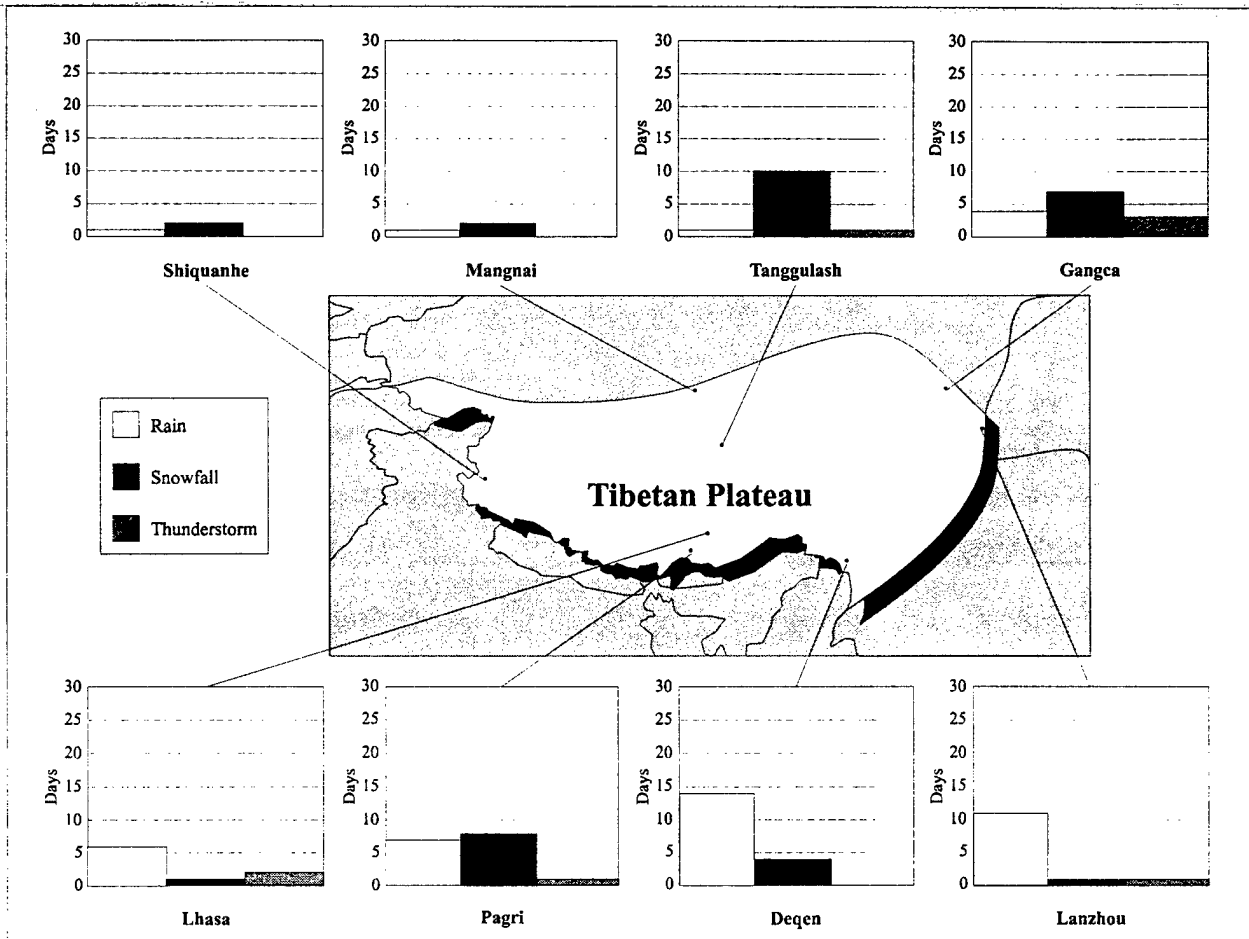


Figure 3-36. October Rain, Snow, and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on average occurrences at scattered locations within the Tibetan Plateau.

Temperatures. Temperatures remain relatively warm in the eastern portions of both regions during fall, but they start to plummet in the western portions and the highest elevations where there is a more continental air mass than in the eastern regions. There is usually a 18 Fahrenheit (10 Celsius) degree difference between the western and eastern portions of the plateau (see Figures 3-37 and 3-38).

Southern Mountain Region. Mean temperatures are warmer than those in the northern highlands with fewer locations receiving subfreezing temperatures. Nearly every location has mean temperatures above 32°F (0°C), regardless of elevation, during September. Generally, October mean minimum temperatures fall below freezing above 11,500 feet (3,500 meters). Mean maximum temperatures range from 75°F (24°C) in September to 45°F (7°C) in October; mean minimums drop from an average of 48°F (11°C) in September to 14°F (-7°C) in October. Record highs range from 99°F (37°C) in the southeast to 63°F (17°C) in the

central Himalayas. Record lows range from 48°F (9°C) in the east to 6°F (-21°C) in the central Himalayas.

Northern Highlands and Basins. Mean minimums and maximums remain above 32°F (0°C) at nearly all locations during September. Mean temperatures remain above freezing during September, but by October, most locations above 6,600 feet (2,000 meters) have mean minimum temperatures below that. Mean maximum temperatures range from 72°F (22°C) in September to 37°F (3°C) in October. Mean minimums drop from an average of 52°F (11°C) in September to 14°F (-10°C) in October. Record highs range from 91°F (33°C) (at Lanzhou—elevation 4,981 feet (1,518 meters)) in the east to 61°F (16°C) (at Tuotuohe—elevation 14,879 feet (4,535 meters)) in central portions where some of the highest reporting stations are located. The same locations recorded the extreme lows 41°F (5°C) to -36°F (-38°C), respectively.

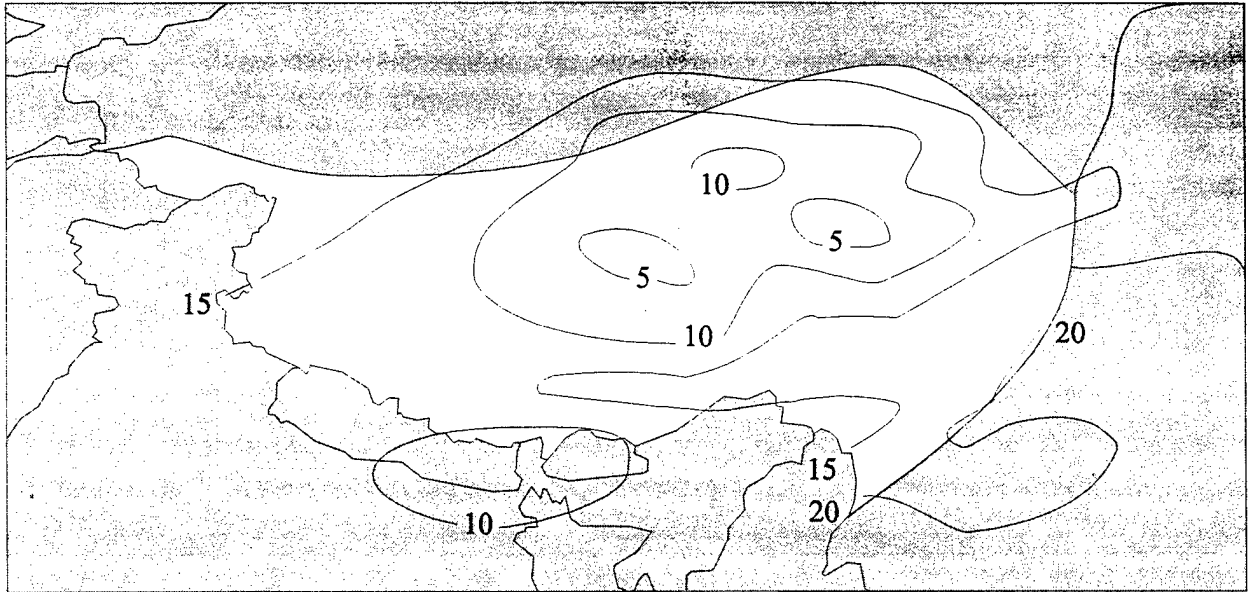


Figure 3-37. October Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for fall.

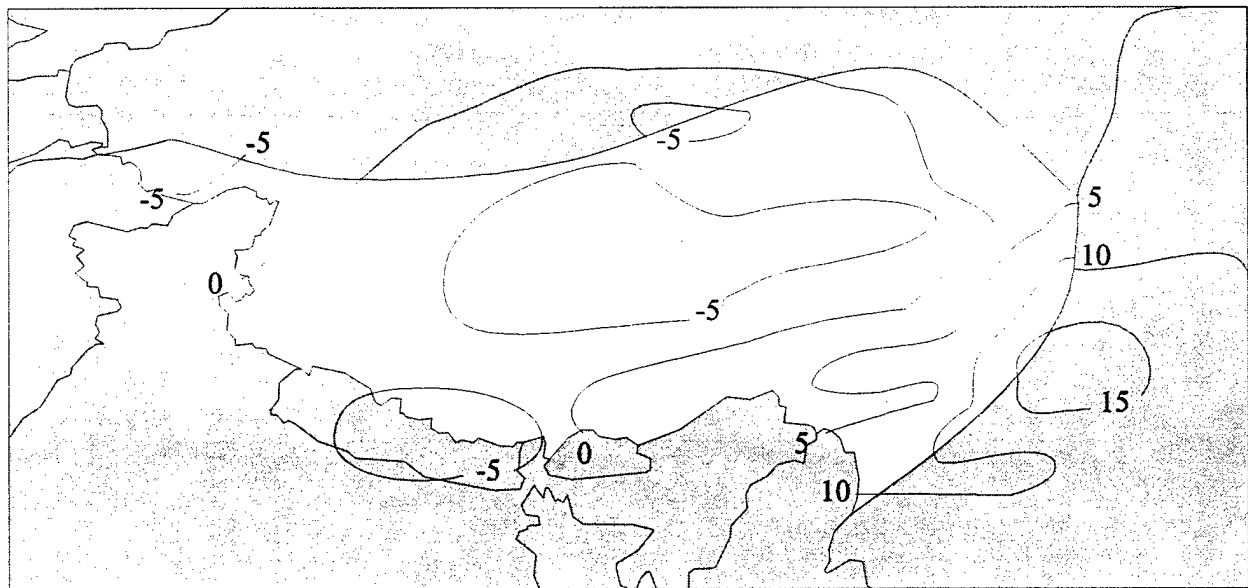


Figure 3-38. October Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average low temperatures for fall.

Hazards.

Turbulence. During fall, clear air turbulence begins to become more of a problem. Clear air turbulence can be expected near the tropopause. Heights of the tropopause are 33,000 to 46,000 feet (10 to 14 km). During fall, the jet stream branches west of the Tibetan Plateau. One branch goes north and the other south. The two branches join again over Japan. Wind speed increases in eastern Tibet partly because of this downstream confluence and gradually weakens westward. Clear air turbulence can occur nearly anywhere on the plateau, but the most likely area is in the eastern part of the plateau where the winds strengthen.

Since the jet stream is north and south of the area, wind speeds are west to southwest at 25 to 35 knots at 18,000 to 25,000 feet (5 to 8 km). This creates potential for moderate-to-severe mountain-wave turbulence. Most likely, this type of turbulence can be expected below 20,000 feet (6 km) west of 90° E on the lee side (north) of the Great Himalayas, east of the Karakorum Mountains in western Tibet, and over the north-south oriented ranges in southeast parts of the plateau.

Moderate-to-severe turbulence can be expected in the vicinity of thunderstorms in early fall. Since isolated thunderstorms are normally visible, aircraft can usually avoid the hazardous effects of thunderstorms. Caution must be exercised when thunderstorms are obscured by lower clouds.

Icing. During fall, the mean height of the freezing level decreases to between 4,000 to 6,000 feet (1 to

2 km) above the terrain. Tops of icing generally extend to 30,000 feet (9 km) MSL. The most severe icing conditions are found in the upper-half of tall cumulus clouds prior to the thunderstorm stage and immediately before rain begins to fall. Mixed icing can be expected during the dissipation stage when clouds flatten into layers of stratocumulus and altocumulus. Under most circumstances, thunderstorms only cover a small portion of the area and are easily circumnavigated. Thunderstorm occurrences decrease in fall and pose no threat to aircraft. Clear icing is the most common type of ice found in thunderstorms. Stratus and stratocumulus clouds normally have ice in fall because the freezing level is low enough. Light-to-moderate mixed (clear and rime) icing is possible with altocumulus. Icing occurrences decrease as cloudiness, precipitation, and thunderstorms taper off. The level where icing would be most probable is from 15,000 feet to 25,000 feet (5 to 8 km) MSL.

Hail. Hail can pose a problem to aircraft and to ground operations. In China, small hail is considered less than 5 mm and large hail is greater than or equal to 5 mm. The highest frequency of hail occurs east of 95° E and south of 35° N in the eastern half of the plateau. The most likely areas for hail are over mountains rather than on plains and valleys because the uneven heating and dynamic disturbances that occur over the mountains result in strong convection. More hailstorms are found on windward slopes than on leeward slopes and on southern slopes rather than northern slopes. Danger to aircraft can occur over mountains, on windward slopes, and on the southern slopes of mountain ranges.

Trafficability. The Tibetan Plateau is the world's highest plateau. It is surrounded by massive mountains, many of which have permanent snowcaps and glaciers. The plateau is a mixture of high mountains, hills, and intermontane plains and alpine meadows. It has many wide valleys, basins, lakes, and salt flats. Slopes are gentle to moderate on the plains and hills and steep in the mountains. Most of the soils are coarse-to-medium grained with fine soils in basins and salt flats. In some high mountain meadows, highly organic and peat soils overlay permafrost. When dry, movement conditions are fair to good on the plains and salt flats and in the wide valleys basins. When wet, movement is confined to areas of coarse-grained soils and to established routes. Movement conditions are poor to unsuitable in most hills and

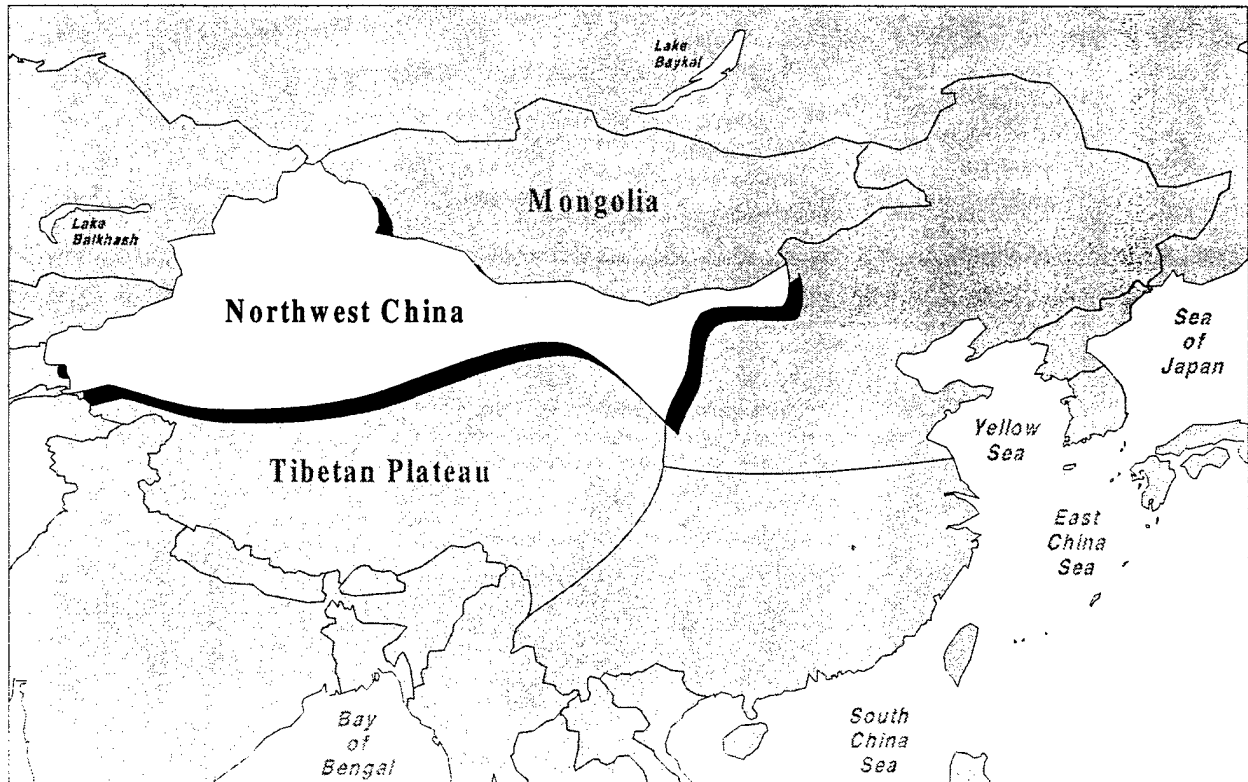
mountains, restricted mainly by steep slopes and rugged terrain. Movement is possible in some broad mountain meadows, especially when they are frozen.

The Sichuan basin is an area in south central China. Within this basin are low mountains, hills, and many streams and terraces that consist of mostly fine-grained soils. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. In the dry season, conditions in the hills and plains are poor to good. Conditions depend on local agricultural practices. Movement conditions are unsuitable in flooded rice paddies and in highly terraced areas. During the wet season, conditions are poor to unsuitable in most places.

Chapter 4

NORTHWEST CHINA

This chapter describes geography, major climatic controls, special climatic features, and general weather (by season) for the climatic zone that makes up the northwest region of China. This zone, as shown below, comprises the entire province of Xinjiang, the northern one-half of Gansu, the northern one-third of Ningxia, and the western one-third of the province of Nei Mongol.



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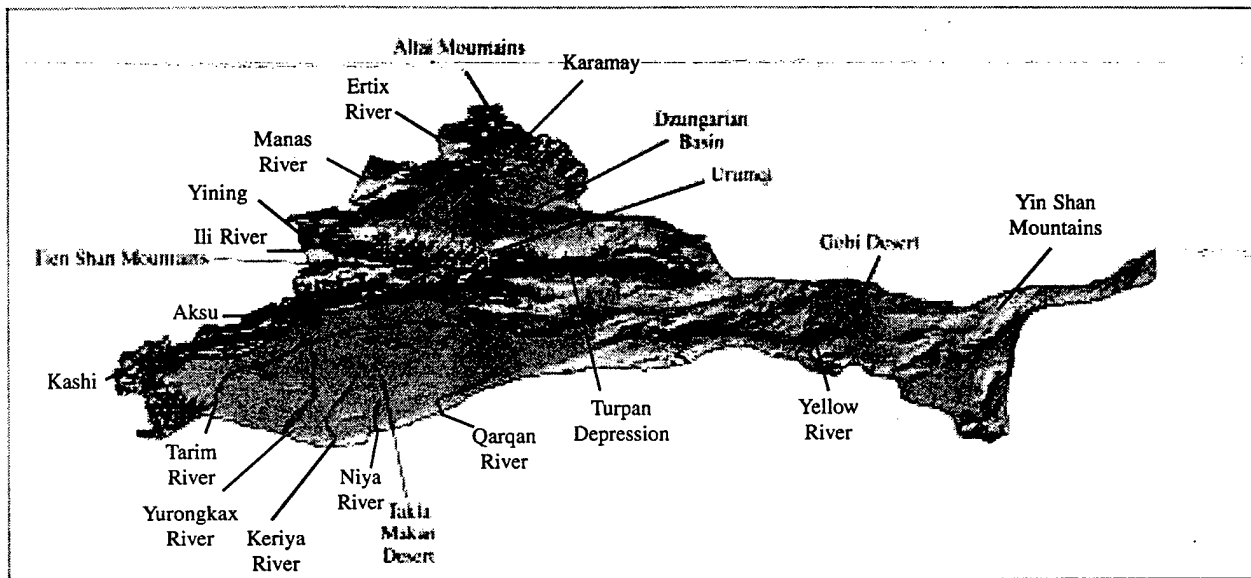


Figure 4-1. Topography. Figure shows the major terrain features of northwest China.

Boundaries. The southern boundary of the arid northwest begins on the Sino-Indian border (35° N, 80° E), extending northeast through the Kunlun Mountain range (approximately 112 miles (180 km)) to the 5,900-foot (1,800-meter) elevation contour on the north rim of the Tibetan Plateau. From this point, the southern boundary follows the 5,900-foot (1,800-meter) contour eastward (approximately 1,100 miles (1,800 km)) just to the west of the city of Ching-T'ai (37° N, 104° E). Extending northeastward, the eastern boundary follows the 200-mm annual isohyet (nearly following the 4,600-foot (1,400-meter) elevation contour) approximately 700 miles (1,150 km) until it reaches the Mongolian

border near Erenhot ($43^{\circ} 39' \text{N}$, 112° E). The eastern boundary separates the eastern edge of the Gobi Desert from the Helan and the Yin mountain ranges and Inner Mongolian. The northern boundary follows the Sino-Mongolian border west through the Gobi Desert and the Altai Mountains until it reaches the point where China, Mongolia, Russia, and Kazakhstan meet. The western boundary of the arid northwest meanders southwest along the international borders between China and, in succession, Kazakhstan, Kyrgyzstan, Tajikistan, Afghanistan, Pakistan, and India. The last section of the western boundary follows the Chinese line of control through the disputed border area with India to 35° N, 80° E.

NORTHWEST CHINA GEOGRAPHY

Mountains. There are three primary mountain ranges and several minor ranges found in northwest China. They extend along the northern periphery of the Tibetan Plateau in a west-northwest to east-southeast orientation. The Kinlun Shan Mountains are out of the Karakorum Range found in northeast Pakistan. This range has an average elevation of 16,400- 19,700 feet (5,000-6,000 meters). Several peaks are above 23,000 feet (7,000 meters). Among them, Kongur Shan, which is located just south of the city of Kashi, has an elevation of 25,300 feet (7,700 meters), and Mustag, in the central portion of the range near the city of Hotan, has an elevation of 23,900 feet (7,300 meters).

The Tien Shan Mountains are second in magnitude to the Kunlun Shan but are at the heart of this region. The Tien Shan bisects Xinjiang province in a west-to-east orientation and separates the Dzungarian basin to the north from the Tarim basin to the south. Additionally, the Turpan depression is found at the base of the easternmost extremity of the Tien Shan. The average height of this range is approximately 13,100-16,400 feet (4,000-5,000 meters); however, two peaks stand above the rest. Pik Pobedy, at an elevation of 24,400 feet (7,400 meters), is found in the extreme western portion of the range, near the junction of the Chinese-Kazakhstan-Kyrgyzstan border. At an elevation of 17,900 feet (5,400 meters), Bogda Feng stands in the center of the range near the city of Urumchi. Karlik Shan, at the eastern tip of the Tien Shan, rises to a height of 16,200 feet (4,900 meters). The Tien Shan is also a region rich in deposits of coal, oil, and metallic ores.

The Altai Mountains, at the northernmost part of northwestern China, form a portion of the border with Mongolia. They have a northwest-southeast orientation. The Altai Mountains have an average elevation of 9,800 feet (3,000 meters), but the highest peak in the range, Nayramadin Feng, located

on the border with Mongolia, rises to a height of 14,400 feet (4,400 meters).

Other minor ranges have an average elevation from 6,600-13,100 feet (2,000 to 4,000 meters). Among them are the Altun Shan Range (along the southeast periphery of the Tarim basin), the Baytik Shan Range (separates the Dzungarian basin from southwest Mongolia), and the Bei Shan Range (separates the Tarim basin from the province of Nei Mongol). The main mountain range of Inner Mongolia is the Qilian Range, which separates the southern extent of the Gobi Desert from the northern fringes of the Tibetan Plateau. Qilian Shan, at a height of 18,200 feet (5,500 meters), is the highest peak in the range. From west to east, the Bor Ul, Longshou, Helan, and Yin mountain ranges form the border of Inner Mongolia and the Gobi Desert.

Deserts. Framed by the Tien Shan Mountains to the north, the Kunlun Shan to the south and west, and the Altun Shan and Bei Shan ranges to the east, the Tarim basin is the primary basin in northwest China. The Tarim basin covers an area of 557,000 km². The average elevation slopes from 4,600 feet (1,400 meters) in the northwest to 2,500 feet (760 meters) in the southeast near the salt marshes of Lake Lop Nur. The Takla Makan Desert makes up most of the area of the Tarim basin.

To the north of the Tien Shan Mountain range, lies the second largest basin in northwest China, the Dzungarian basin. This basin covers an area of approximately 90,000 km². The Dzungarian basin is basically flat with a gentle slope to the southwest. Elevations average between 1,000-1,500 feet (300-500 meters) and descend to 630 feet (190 meters) in the center of the Gurbantunggut Desert. The Dzungarian basin is surrounded on the west by the Tien Shan Mountains and on the east by the Altai Mountains. The north and northwest of the basin is open to Siberia by the Irtysh valley.

A genuine topographic anomaly is found at the easternmost tip of the Tien Shan Mountains—the Turpan depression. The lowest elevation at the heart of the depression descends to 500 feet (150 meters) below sea level, 220 feet (70 meters) lower than the elevation of Death Valley. Like its American counterpart, the Turpan depression is also the driest point in China.

The southern one-half of the Gobi Desert comprises the eastern periphery of Northwestern China. Framed by the Bor Ul Mountains on the west, the Qilian and Longshou ranges to the south, and the Helan and Yin Shan ranges to the east, the southern Gobi Desert is actually made up of two sub-deserts. The Badain Jaran Desert is found in the northern two-thirds of the region, and the Tenggei Desert is found at the southern end of the region.

Lakes, Rivers, and Drainage. As a rule, the rivers of northwest China originate in the glaciers high in the area mountain ranges and flow into the major basins before they end in the deserts. These rivers traverse the deserts only during major flood years. The main river system in northwest China is the Tarim River. This river has a source region high in the glaciers of the western Kunlun Shan Mountains and extends north and east around the periphery of the Tarim basin before it feeds into the Konqi River and ends in the salt-encrusted marshes and Lop Nur Lake at the eastern end of the basin. Several glacier-fed minor rivers originate in the mountains of the region before they evaporate in the barren wastelands of the deserts. Principal tributaries that feed the Tarim River from the Tien Shan Mountains are the Kizil, Kaxgar, Toxhan, Aksu, and Muzat. Several minor rivers also originate in the central Kunlun Shan and flow into the southern Takla Makan Desert. Among these are the Karokax, Yurongkax, Keriya, Niya, Karamiran, and Qarqan rivers.

The primary river found in the Tien Shan Mountains is the Ili River. The Ili River originates in the central Tien Shan Mountains and flows west into Kazakhstan. Other minor rivers that feed the Ili River are the Tekes, Kiines, and Kax. Additionally, the Kaidu River flows westward from its headwaters in the Tien Shan Mountains before it changes

directions and flows east to empty into Bosten Lake.

The Bortala and Kuytun rivers feed Lake Ebinur just to the north of the town of Jinghe. The Manas River flows into Lake Manas, but during drought years, the Manas dries up. Several other minor tributaries from the mountains near the city of Hoboksar feed Lake Manas. The headwaters of the Emin River are found in the mountains to the east of the city of Tacheng before the river crosses the Sino-Kazakhstan border to empty into Lake Alakol. The Ertix River and the Burqin River join in the northern Altai Mountains and flow into Lake Zaysan across the border in northeast Kazakhstan. Finally, the Ulungur River in the Altai Mountains feeds Lakes Ulungur and Jili.

Seasons. Dominated by the cold, dry air mass of the Siberian high in winter and shielded from the effects of the southwest monsoon by the Tibetan Massif in summer, northwest China is the driest part of China. It has some of the most arid places on Earth. These two seasons are separated by two brief transitional periods. March and April provide the transition from winter to summer, and even more brief, the latter part of September and October constitute the rapid onset of winter.

Vegetation.

Mountainous Regions. A large portion of the mountainous terrain of northwest China is covered by permafrost. In the Tien Shan Mountains, a total of 98,000 km² is covered, while the Altai Mountains are covered by 34,000 km² of permafrost. The Qilian Shan Mountains are covered by 134,000 km² of permafrost. Instead of being formed according to latitude, the formation of permafrost is entirely elevation-dependent in northwest China. On the Altai Mountains, the permafrost line is found at the 6,890-foot (2,100-meter) level, while in the northern Kunlun Shan Mountains, the permafrost level is found at the 13,616-foot (4,150-meter) level. Much of the central and western Tien Shan Mountains are covered by glaciers, some nearly 35 km in length. A large portion of the Kunlun Shan Mountains, from Kashi south along the border with the Karakorums, is glacier covered. Below the permafrost level, the mountains are predominantly

NORTHWEST CHINA GEOGRAPHY

covered by alpine meadow steppes, among the best grazing regions in China.

Desert Regions. The deserts of northwest China are some of the most barren territory to be found. These arid regions are cut off from distant moisture sources by the highest mountains in the world. With the exception of small shrubs and grasses in the

proximity of rivers along the periphery of the area basins, the deserts are devoid of vegetation. The majority of the deserts are covered by barchans (crescent-shaped dunes that travel). These dunes are very rarely covered by vegetation. The eastern Tarim basin, in the vicinity of the salt marshes near Lop Nur, is sparsely populated by stunted bushes and marsh grasses.

MAJOR CLIMATIC CONTROLS

The Siberian High. This semipermanent wintertime feature is the strongest cold anticyclone in the world. Firmly entrenched in the vicinity of Lake Baikal by late September, the Siberian high dominates the weather of northwest China until late April. This shallow dome of cold, dry air, trapped in the Tarim and Dzungarian basins, rarely extends above 850 mb. The province of Xinjiang is in the southwestern quadrant of the high, and the Gobi Desert lies in the southeastern quadrant. At its strongest, from December to February, the Siberian high acts as an effective block to all but the most vigorous frontal systems. Arctic air, which originates in the Greenland Sea, enters Siberia in the vicinity of Novaya Zemlya, and reinforces the Siberian high. In late March, as the high weakens, frontal systems are able to affect the region.

The Tibetan 200-mb Anticyclone. This semipermanent upper-air cell not only acts as an upper-level heat source but also as an outflow mechanism for sustaining surface monsoon trough convection between May and October. The anticyclone begins to form in late April to early May as the latent heat of condensation from widespread convection over Myanmar warms the troposphere. Strong surface heating on the Tibetan Plateau, at a mean elevation of about the 500-mb level, shifts this massive upper-level high to Tibet in late May or June. The mean July 200-mb flow pattern over south-central Asia shows the large-scale anticyclone anchored over the Tibetan Plateau. This position places northwest China in the path of deep westerlies and provides a direct path for the advection of mid- and upper-level moisture from the Atlantic Ocean.

By August, moderate snow cover produced by strong, southwest monsoon convection begins to

lower surface temperatures and increase the surface albedo by reflecting more radiation away from the surface. The large amount of heat energy that would normally have been used for surface heating is now used to melt the snowfall and evaporate the runoff. Surface temperatures are affected immediately, but cooling aloft is gradual. Typically, it takes 1 to 2 months for surface cooling to affect the upper levels. Satellite research showed that the Tibetan Plateau is snow-free 80 percent of the time during the early southwest monsoon. The upper-level anticyclone weakens by October because the surface "trigger" is eliminated; upper-level westerlies move southward over the plateau. This places northwest China under northwesterly flow aloft and effectively eliminates the advection of Atlantic Ocean moisture.

The Azores High. This semipermanent pressure feature, centered near the Azores Islands, plays an important role in bringing mid- and high-level moisture into northwest China. Even though the Atlantic Ocean is thousands of miles away, it is the primary source of moisture. The Azores high imports moisture into frontal systems as they enter western Europe. These frontal systems normally bring only mid- and high-level moisture to northwest China. In July, as the Azores high moves to its mean northernmost position, near 35° N, 30° W, the amount of moisture advected into northwest China peaks. With the polar jet and the storm track situated over northern Xinjiang, the westerlies carry moisture directly from the Atlantic Ocean into northwest China. As the Azores high retreats south, the moisture source is cut off. By January, the driest month in northwest China, the Azores high is at its mean southernmost position, near 29° N, 30° W. The polar jet and its storm track are also shifted south of the Tarim basin.

Duststorms/Sandstorms. Even though duststorms and sandstorms can occur any time during the year, the increased number of frontal passages make spring the primary season for this phenomenon. The two primary factors required for duststorms/sandstorms are strong solar heating and mean wind speeds greater than 15 knots. Arid soil and sparse vegetation make the deserts of Xinjiang, Gansu, and the Gobi prime areas for this phenomenon. During the 30 or more sandstorms that occur in the region each year, both dust and sand are lifted as high as 13,000 feet (4,000 meters) AGL. Visibility is restricted to near zero for usually 2 hours, but conditions can persist for as long as 24 hours. Sandstorms that originate in the Gobi Desert have far-reaching effects on the territory to the south and east, while storms in the Tarim basin are "bottled up" by the surrounding mountain ranges. During the most vigorous Gobi Desert sandstorms, sand is clearly visible on satellite imagery as far away as Japan, Korea, and Taiwan. These storms have historically contributed to the vast loess deposits in the provinces of Shanxi and Shaanxi. They amount to a depth of more than 100 meters in some places. To a lesser extent, the loess deposits also extend farther south through the Chinling hills and into Henan Province.

Blowing dust and sand are the most common and the most serious hazards to operations in northwest China (see Figure 4-3). Dust is a finer, smaller atmospheric particle that is nearly always present in the deserts. Sand is a larger, more coarse particle that requires greater wind speeds to be lifted and transported. Additionally, stronger winds and longer trajectories will cause sand and dust particles to be lifted higher. Aircraft downrush raises dust and sand from the desert floor and reduces visibility in the immediate vicinity of the aircraft. Also, dust and sand enter engine intakes and cause damage. During severe sandstorm conditions, ablation of windscreens and other aircraft parts can occur. Persistent dust conditions also cause problems with dry skin, sore throat, and cracked lips for people. Dust also contributes to radio signal degradation. When windblown particles strike an object a heavy electrostatic discharge may result. The surprisingly high-voltage sparking associated with these electrostatic discharges can pose a hazard to personnel and equipment.

The most favored locations for blowing dust and sand are found along the southern rim of the Tarim basin, on the edge of the Taklamakan Desert. The persistent winds blowing across the desert account for the high occurrence of blowing sand or dust, especially along the southern rim of the Tarim basin. Numerous locations in this region average more than 150 days a year. Hotan tops the list at 243 days a year and Minfeng comes in second with 189 days. On the average, Hotan reports either blowing dust or sand on 81 of the 90 days in spring and 75 of the 90 days in summer. Conversely, stations located along the northern rim of the Tarim basin average less than 70 days a year of blowing sand or dust. Sites in the northern Gansu and Gobi deserts average 30-60 days a year. As is expected, sites in the Tien Shan and Altai mountains have the lowest incidence of blowing sand or dust across the region. Most locations there average less than 10 days a year.

Mountain-Wave Turbulence. Strong, post-frontal, northerly winds that blow perpendicular to the east-west oriented Tien Shan Mountains produce conditions conducive to mountain-wave turbulence. With sufficient moisture available, altocumulus standing lenticular (ACSL) clouds will form on the lee side of the ridge line. However, since the air is usually too dry, ACSL will not normally be present. Moderate-to-severe turbulence will still exist up to 45-60 miles (75-100 km) downstream and to an altitude of 45,000 to 95,000 feet (15 to 30 km).

The interaction of the wind with the mountaintops forms a sinusoidal-wave pattern. As each successive downdraft accelerates the air parcel to the surface, the wind speed increases, and lifts blowing dust and sand. If there is sufficient moisture available, ACSL will form as each updraft cools adiabatically near the apex of the sine wave until the mountain wave dissipates downstream. Intensification or weakening of the wind speeds across the mountaintops will change the configuration of the mountain wave.

Surges of cold air after frontal passages cause intensification of the mountain wave. This increase of wind speeds at the mountaintops decreases the wavelength and increases the frequency and amplitude in the downstream wave. As the

SPECIAL CLIMATIC FEATURES

wavelength decreases, the successive updrafts and downdrafts are closer together. This brings the lines of ACSL closer together. The increased amplitude lifts dust and sand higher into the atmosphere. Suspended dust as high as 13,000 feet (4,000 meters) has been reported. Additionally, the higher apex of the sine wave imparts a greater amount of potential energy into the air parcel. This translates into greater kinetic energy when the air parcel contacts the surface. Conversely, as the wind speeds decrease, the wavelength increases, and the amplitude and frequency decrease. The increased wavelength translates into greater spacing between ACSL cloud lines. The decreased amplitude means dust will not

be lifted as high. Potential energy at the apex of the wave is also lower, which signifies less kinetic energy and lower wind speeds at the surface.

The mountain wave usually breaks down on the second day after the frontal passage. The winds shift from a northerly direction to an easterly or southeasterly direction. Once the perpendicular component decreases, the mountain wave, and the resulting turbulence dissipates. The peak time for mountain-wave occurrence is from late winter into spring. This ties in with the weakening of the Siberian high, which opens the storm track into northwest China.

General Weather. Winter is the longest season in northwest China. It lasts an average of 5-6 months. By November, the Siberian high is firmly established and centered between western Mongolia and Lake Baikal in Russia. This shallow dome of cold, dry, continental polar air dominates the climate of northwestern China and brings predominately stable conditions. The Siberian high is evident as a closed anticyclone at the 850-mb level and as a ridge of high pressure at 700 mb. Arctic air entering northern

Siberia travels across the continent to reinforce the center of the anticyclone. Cold fronts associated with these bursts are very shallow and are greatly affected by topography. Since they only extend 4,900 to 6,600 feet (1,500 to 2,000) meters above the surface, these cold surges are blocked once they come into contact with the Altai and Tien Shan mountains. Only the most extreme outbursts are strong enough to be channeled through the Dzungarian basin to reach the Tarim basin and southeastern Xinjiang Province.

Sky Cover. The terrain of northwest China plays a tremendous role in determining the amount of clouds in each layer. The mean amount of total clouds across the region is 30 to 40 percent. Taken by itself, this figure can mislead since the mean amount in the low etage (layer) is between 5 to 10 percent and 60 to 70 percent in the mid- and upper-levels. Figure 4-2 shows the frequency of ceilings below 3,000 feet for selected locations in northwest China.

On the lee side of the mountains, (the south-side of the Tien Shan and the eastern slopes of the western Kunlun Shan), smaller amounts of low clouds are experienced due to downslope foehn winds. Conversely, on the windward sides (the northern slopes of Kunlun Shan, Altun Shan, and Tien Shan, and the western slopes of Altai Mountains and Tien

Shan), low cloud formation is aided orographically and tends to persist. Stratiform type clouds predominate since the stable Siberian high tends to cap vertical development.

In the mid- and upper-levels, the mid-latitude westerlies prevail. The polar jet is situated just south of the region with a long-wave trough placed from eastern Xinjiang to western Tibet. Periodic pulses in the jet stream import mid- and high-level clouds from the Atlantic Ocean. The arctic jet, north of the area across southern Siberia to southern Mongolia, is a secondary source of upper-level clouds. Recurrent cold surges from the Arctic Ocean, along with intensification of the Siberian high, cause the position of the arctic jet and its corresponding low-level front, to shift south into the Dzungarian basin, and occasionally into the Tarim basin.

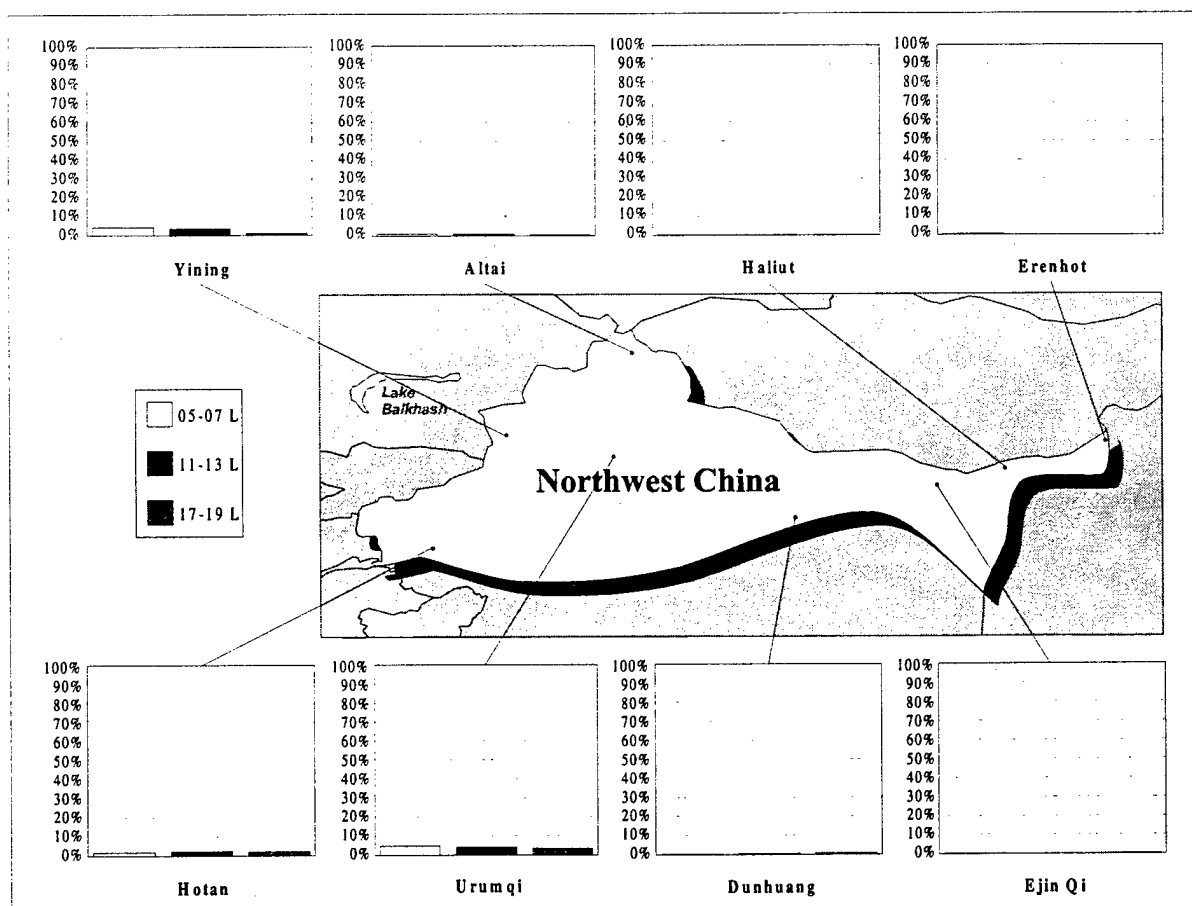


Figure 4-2. January Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Terrain plays a tremendous role in determining the prevailing visibility of this region. Across the desert regions there are less than 5 fog days a year. In the Altai and Tien Shan mountains nearly 25 fog days occur annually. Typically, due to the presence of the dry, shallow Siberian air mass, visibility is excellent below 850 mb. The primary wintertime visibility obstructions in the deserts are blowing sand or dust. In the mountains, fog, rain, and snow account for the higher incidence of reduced visibility. Even though visibility at most desert locations is nearly pristine, the highest incidence of restricted visibility occurs at those desert locations on the south rim of the Tarim basin where the prevailing wind direction is from across the Takla Makan Desert. For instance, both Hotan and Minfeng experience visibility below 4,800 meters up to 50 percent of the time during winter. The frequency of restricted visibility increases at these stations as the winter season progresses. Late winter and early spring are the worst times for restricted visibility caused by high winds associated with the increased number of frontal passages. Each season also shows a diurnal propensity for lower visibility during the morning hours. This is caused by dust suspended below the strong radiational

inversion. As the inversion breaks in late morning, mixing improves the visibility.

Mountain stations are more likely to experience restricted visibility due to the presence of hydrometeors, rather than because of suspended dust or sand. Stations in the Tien Shan and Altai mountains, particularly those stations along the windward sides of these ranges, experience enhanced winter rains, snowfall, and upslope fog conditions. Opposite of desert stations that report increased incidence of restricted visibility in late winter, mountain stations typically have their highest occurrence of restricted visibility in December and January. This time also corresponds to the time of greatest number of snowfall days.

Visibility is excellent across northern Gansu and into the southern Gobi Desert. All locations report visibility below 4,800 meters less than 5 percent of the total winter; most experience these conditions less than 2 percent of the time for the entire year. This is despite a wintertime average of 3-5 blowing dust days a month at stations across this region. Figure 4-3 depicts the frequency of visibility less than 4,800 meters at selected locations.

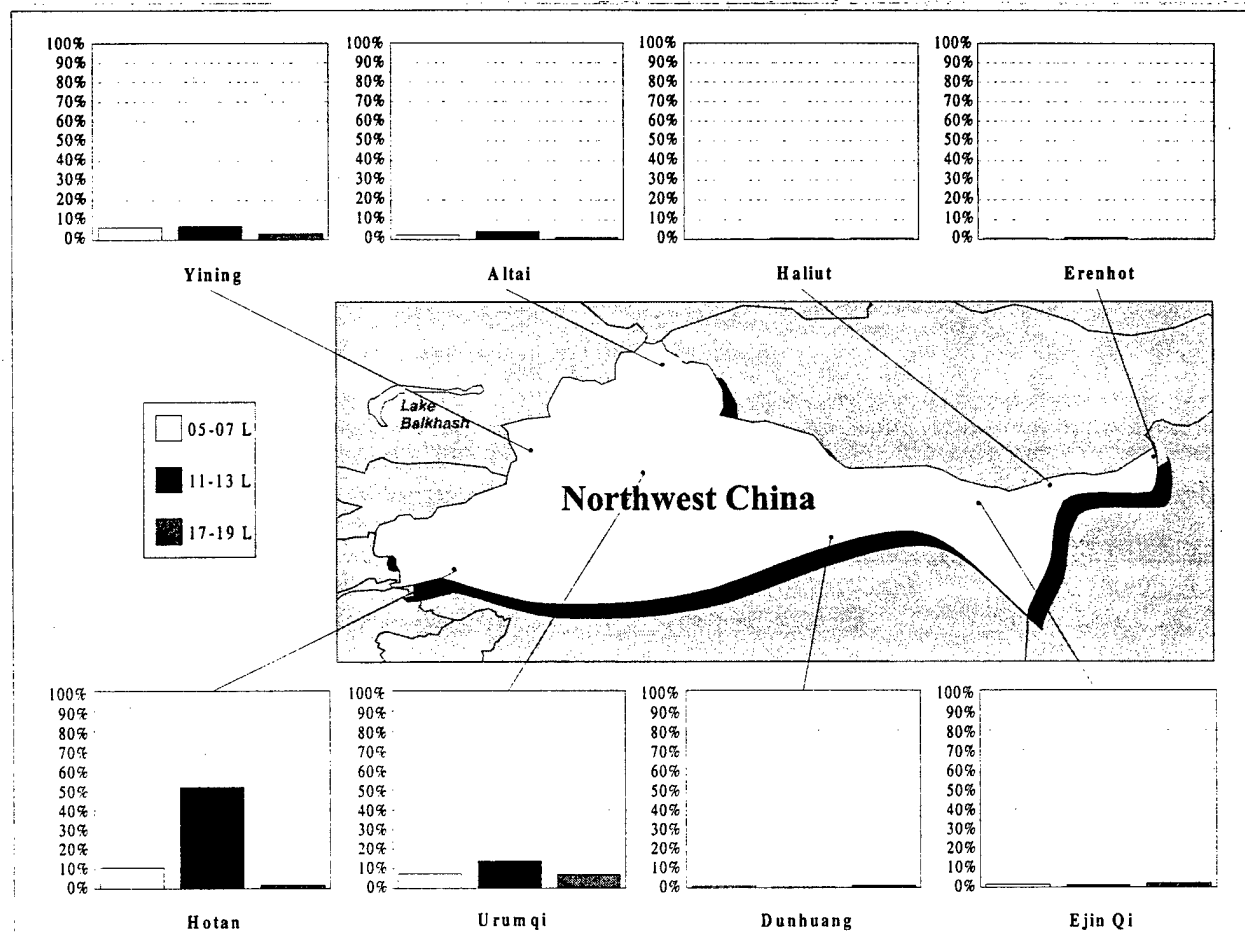


Figure 4-3. January Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. During the winter, the winds in northwest China are largely determined by the position and strength of the Siberian high. Additionally, because the long winter nights enhance the subsidence inversion with radiation inversions, all stations in northwest China report a nighttime maximum of calm winds. There is also an annual maximum of calm winds in the winter. As winter progresses toward spring and the Siberian high weakens, the percentage of time when calm winds are reported also decreases. In Xinjiang Province, under the dome of cold, dry Siberian air, the winds are mostly light and variable. Generally, the only time wind speeds in Xinjiang increase to 15 knots is when they are associated with localized foehn and mountain breezes. A comparison between Figures 4-4 and 4-5 shows the clear effect of terrain and diurnal variations upon the local winds.

Stations located near the Kunlun Shan, Tien Shan, and Altai mountain ranges are susceptible to localized foehn and mountain breeze effects. There is a discernible nocturnal maximum for mountain breezes at sites located near major mountain ranges. These effects are most noticeable at Kashi and Hotan (at the base of the Kunlun Shan), at Yining (on the western side of the northwestern Tien Shan), and at Korla (on the southern edge of the central Tien Shan). The terrain of Xinjiang also tends to block the effects of migratory frontal systems in most locations and intensify their effects in other locations. The extremely high mountain ranges that surround the Dzungarian and Tarim basins effectively block the effects of winds associated with frontal passages. There are, however, numerous mountain passes in the Tien Shan and Altai ranges that induce a venturi effect for winds that funnel into northwest China from Kazakhstan and Siberia. Irtysh Valley, in the northern Altai Mountains, funnels the cold, shallow Siberian air mass into the Dzungarian basin. Ala Pass, a low, narrow passage lodged between mountains several thousand meters high, is the most famous of the

many passes along the border with Kazakhstan because of its funneling effect. The southeastern end of the pass, near Lake Aibi, records an average of 166 days a year of wind speeds in excess of 34 knots. This lake is known locally as "the Lake for Winds." Hoboksar, with a wind speed of 62 knots, holds the record for the highest wintertime wind speed in Xinjiang.

Compared to Xinjiang, the terrain in northern Gansu Province, the Gobi Desert, and Inner Mongolia has a minimal impact on the windflow from the Siberian high. Arctic outbreaks blow unabated through the desert and carry large amounts of dust and sand into neighboring provinces. Unlike stations found in Xinjiang, stations in the Gobi Desert region experience a comparatively low percentage of calm winds. Still, like all stations in northwest China, there is also a nocturnal maximum for calm winds and the overall percentage of calm winds decreases as spring approaches. Sites in the southeastern quadrant of the Siberian high, experience a high percentage of northwesterly winds. Haliut, a city in the northeastern Gobi Desert and just north of the Yin Mountains, exhibits the typically high percentage of northwesterly winds associated with the Siberian high. Haliut also reports an afternoon maximum of southerly winds, with speeds less than 15 knots. Directly south of Haliut, there is a gap in the Yin Mountains that allows the cooler air from south of the mountains to funnel into the warmer, drier desert region. As the drier soil of the desert warms more rapidly than the area to the south of the mountains, a temperature contrast is created; by afternoon, a southerly wind blows through the pass. This effect is rarely enhanced, since the mean winds speeds do not exceed 15 knots; however, the effect may be extended if the region south of the mountains is overcast for a prolonged period. This is normally a short-term effect that dissipates after sunset. As night falls over the desert and the dry air cools more rapidly than in the region south of the mountains, a temperature equilibrium is reached. Because of the inherent differences in the soil types, the effect occurs year-round.

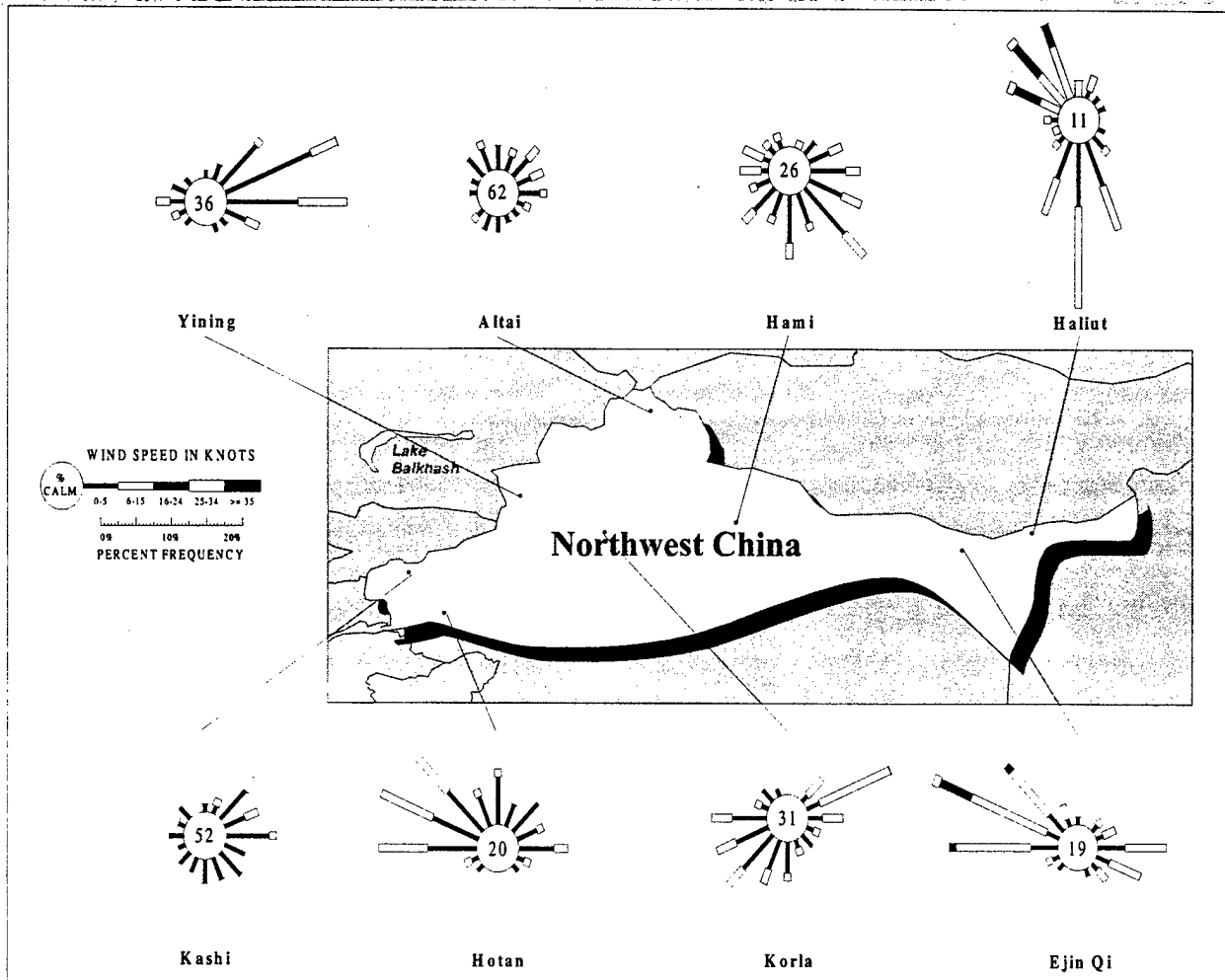


Figure 4-4. January 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on frequency and location.

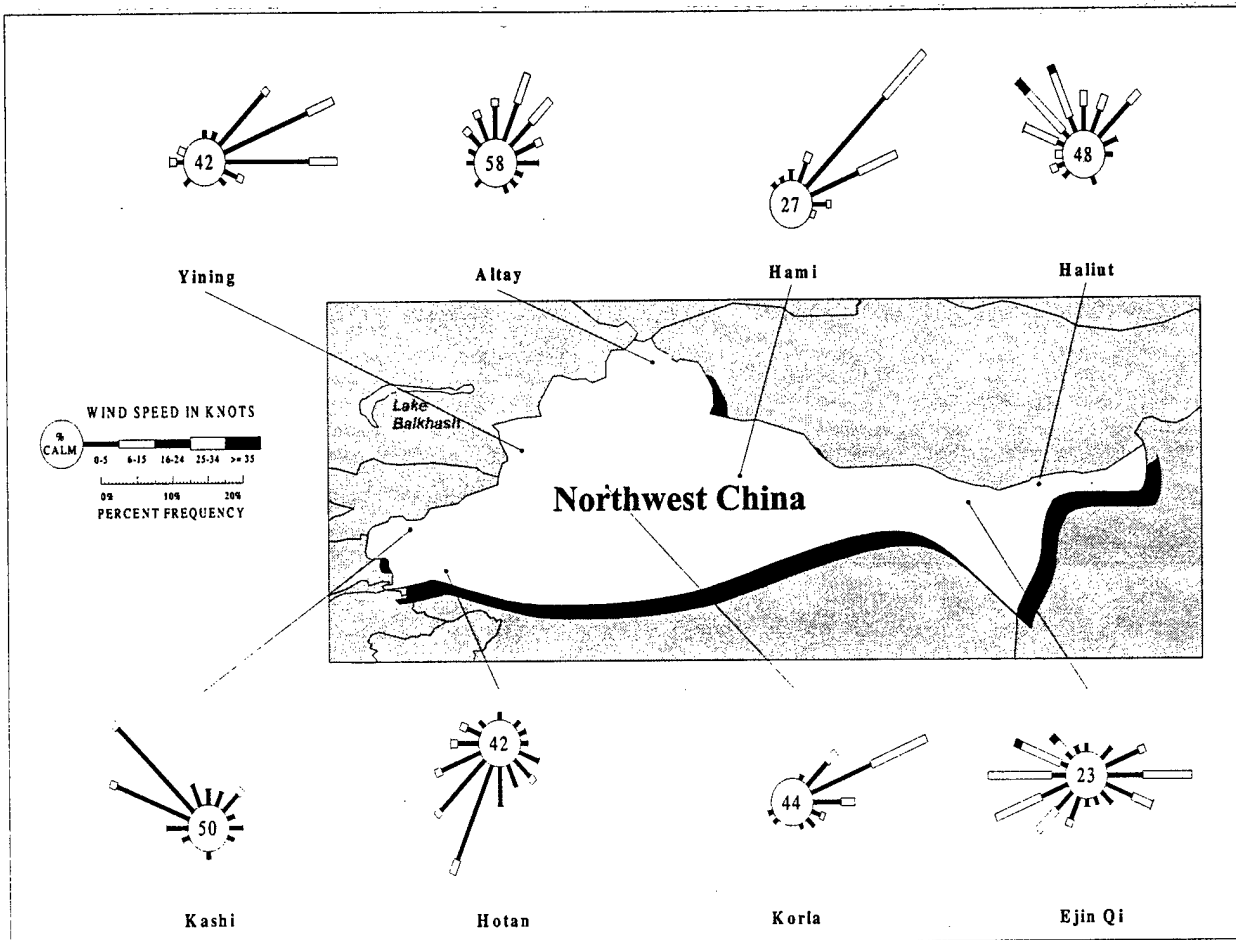


Figure 4-5. January 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on frequency and location.

Winds Aloft. In winter, the mean polar jet is located south of the Tibetan Plateau. The arctic jet is situated north of the region over southern Siberia. This places northwest China in the belt of mean westerlies. The second most-favored wind direction is west-northwesterly. This is a reflection of the incursions of the arctic jet associated with outbreaks of arctic air. At 850 mb, the mean wind flow is determined by the station's placement with respect to the location and intensity of the Siberian high. At Altai, which is located south-southwest of the mean center of the Siberian high, southeasterly winds prevail at 850 mb. Meanwhile, at Ejin Qi,

southeast of the mean center, northwesterly winds prevail.

While wind speeds vary little at the 500- and 300-mb levels, the 850-mb wind speeds are much higher at sites in the Gobi Desert region than at those in Xinjiang. At all sites, wind speeds are higher at the end of winter than at the beginning. Maximum wind speeds at 300 mb are 120 knots for most of winter and increase to 150 knots in March. The maximum winds speeds only occur less than 2 percent of the time. Wind speeds and directions for standard pressure levels at Altai are depicted in Figure 4-6.

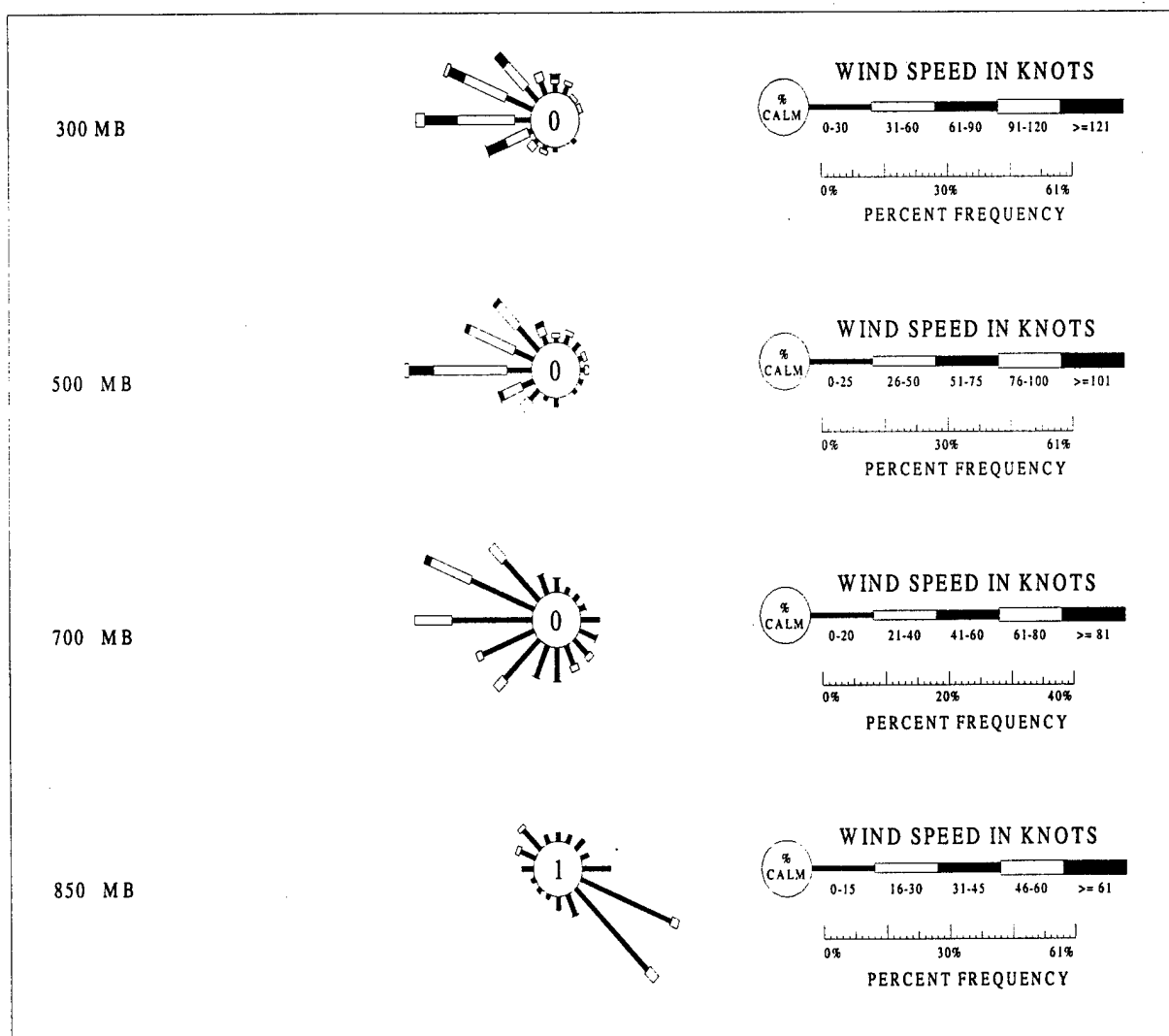


Figure 4-6. January Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Altai.

Precipitation. The Takla Makan Desert is an area of exceptionally sparse precipitation with most stations reporting less than 10 mm for the entire winter season (approximately one-fifth of the annual total of 50 mm). Strong subsidence and dry northeasterly flow from the Siberian high inhibits precipitation. Migratory frontal systems, which enter from central Asia and temporarily weaken the Siberian high, are blocked from the Tarim basin by the Tien Shan Mountains. Several gaps in the Irtysh Valley allow the intrusion of frontal passages and moisture incursions from the Atlantic and Arctic oceans into northern Xinjiang. Dzungarian basin records the majority (60-80 percent) of its annual precipitation during the winter as a result of these frontal passages. Only rarely do exceptionally vigorous systems produce precipitation in the Tarim basin.

Bayan Mod, in the heart of the Badain Jaran Desert, is especially dry during the winter. It receives only 5.8 mm of precipitation. This 5-month total

represents barely 5 percent of the annual precipitation total of 100 mm. The driest months are December-February, with a scant 3-month total of only 1.8 mm.

Orographic lifting enhances snowfall and rainfall on windward slopes and higher peaks of the Tien Shan and Altai mountains. Migratory pressure systems enter northwestern China from central Asia, Siberia, and Tibet, and move to the east through Inner Mongolia. On the average, a total of 25 frontal systems affect northwestern China in the winter. Twelve come from the west, five from the northwest, and eight from the southwest. Fronts from the west and northwest have the Atlantic and Arctic oceans as their main moisture sources. These fronts deposit their precipitation primarily along the western faces of the western and northern Tien Shan and along the western slopes of the Altai Mountains. Figure 4-7 shows the scarcity of precipitation during the most representative month of winter.

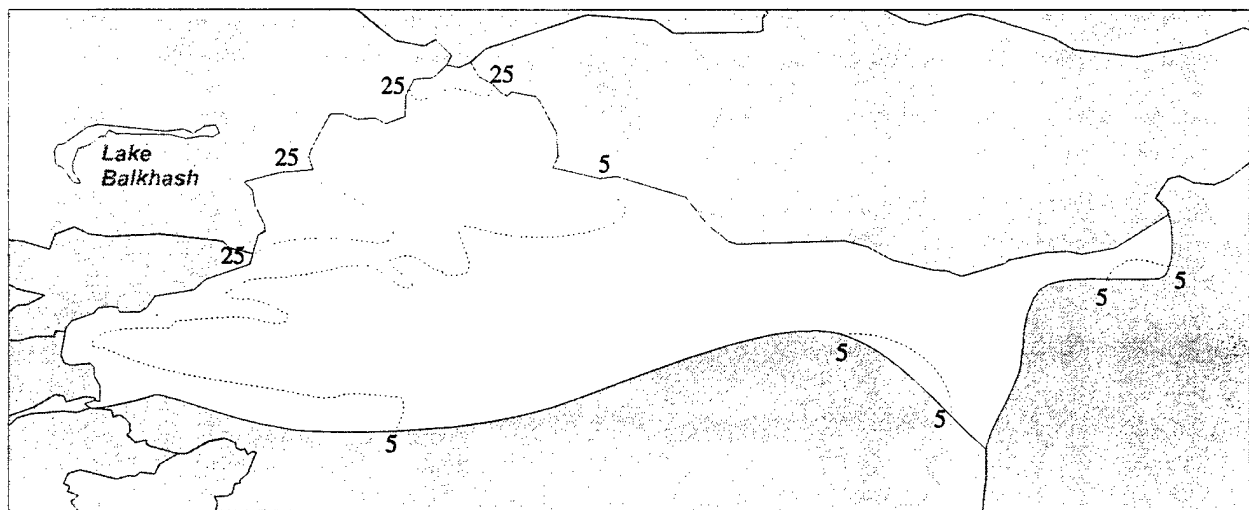


Figure 4-7. January Mean Precipitation (mm). The isopleths show the contrast between the amounts of precipitation recorded in the mountains and the deserts.

Snow Cover. There is a stark difference between the number of days with snow in the mountains and deserts of northwest China. This difference is clearly shown in Figure 4-8. The Tarim basin and southern Gobi Desert average less than 10 days a year. The Turpan depression averages less than 1 day a year. It is not unusual for several years to pass between snowfalls at the Turpan depression. Isolated stations in the Tien Shan Mountains average 60-80 days a year of snowfall. Higher elevations in the Tien Shan record more than 100 days—the highest is 175 days a year at Xiaoquzi on Tianshan Mountain. The Dzungarian basin, susceptible to frontal passages and not quite as dry as the Tarim basin, averages 30-40 days a year of snowfall. Stations in the Altai Mountains average more than 40 days of snowfall a year. Mean annual snowfall day averages on mountain peaks increase to between 60-80 snow days a year. Jiuquan and

Zhangye, located between the northeastern edge of the Qilian Mountains and the southern Gobi Desert, average 24 and 29 snowfall days a year, respectively. Erenhot, Mandal, and Haliut, on the extreme northeastern fringe of the Gobi Desert north of the Yin Mountains, average 28-36 snow days a year.

The annual mean number of days with snow cover is a function of elevation. The Tien Shan and Altai mountains have more than 150 days of snow cover, but the Tarim basin only reports about 10 days a year. The Turpan depression, the lowest elevation in the region, has less than 1 day a year of snow cover. In the Dzungarian basin, the annual mean is approximately 50 days a year. Northern Gansu and the southern Gobi Desert average from 10-25 days of snow cover per year. This number gradually increases to 50 days in the northeastern Gobi Desert.

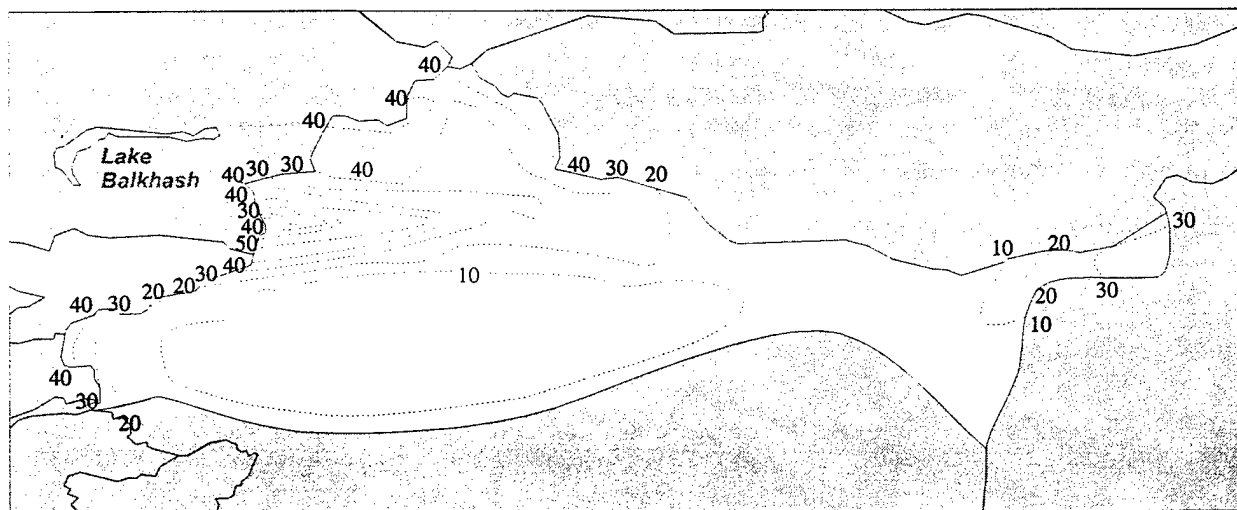


Figure 4-8. Mean Annual Number Snowfall Days. The isopleths on this chart show the highest number of snowfall days occurs in mountainous terrain.

Temperatures. In January, the coldest month of the year, northwest China endures the full brunt of the Siberian high. Mean daily temperatures for the entire region are well below freezing. Both

topography and elevation are important factors in determining the mean temperature and diurnal variation of stations across the region. These effects are sharply defined in Figure 4-9.

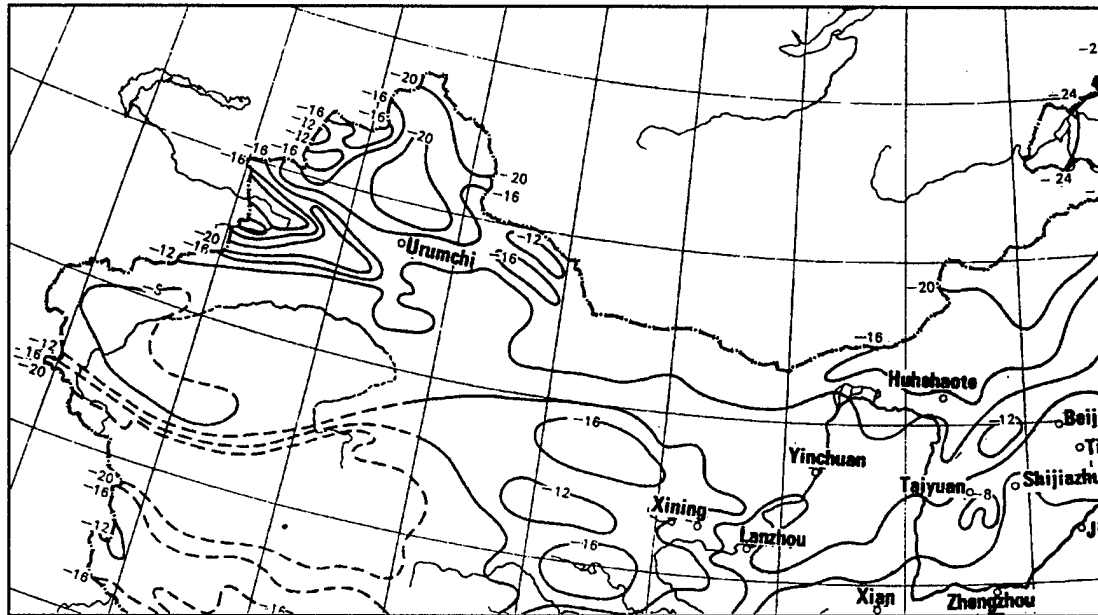


Figure 4-9. Mean January Temperatures (°C). The isopleths on this chart show the correlation between elevation and mean temperature. The dashed lines indicate extrapolated temperature data.

Mean January temperatures range from 23°F (-5°C) in the western portion of the Tarim basin to -22°F (-30°C) at isolated locations in the western Tien Shan Mountains. In the southern Gobi Desert mean temperatures average from 10°F (-12°C) to 3°F (-16°C), and approach -4°F (-20°C) in the northeastern Gobi. The Altai Mountains are also in the zone of -4°F (-20°C) mean temperatures and the -4°F (-20°C) isotherm encircles the Dzungarian basin to enclose the largest pool of cold air in China.

The Tien Shan and Altai mountains act as a barrier to the shallow pool of arctic air from the Siberian high. Cold air flows into the Dzungarian basin from Siberia through the Irtysh valley. In the central Tien Shan, and the southern Altai, this pool of arctic air creates a peculiar temperature distribution. Figure 4-10 shows mean temperatures are actually colder at the lower elevations in the basin than at stations 3,300-4,900 feet (1,000-1,500 meters) higher in the nearby mountains.

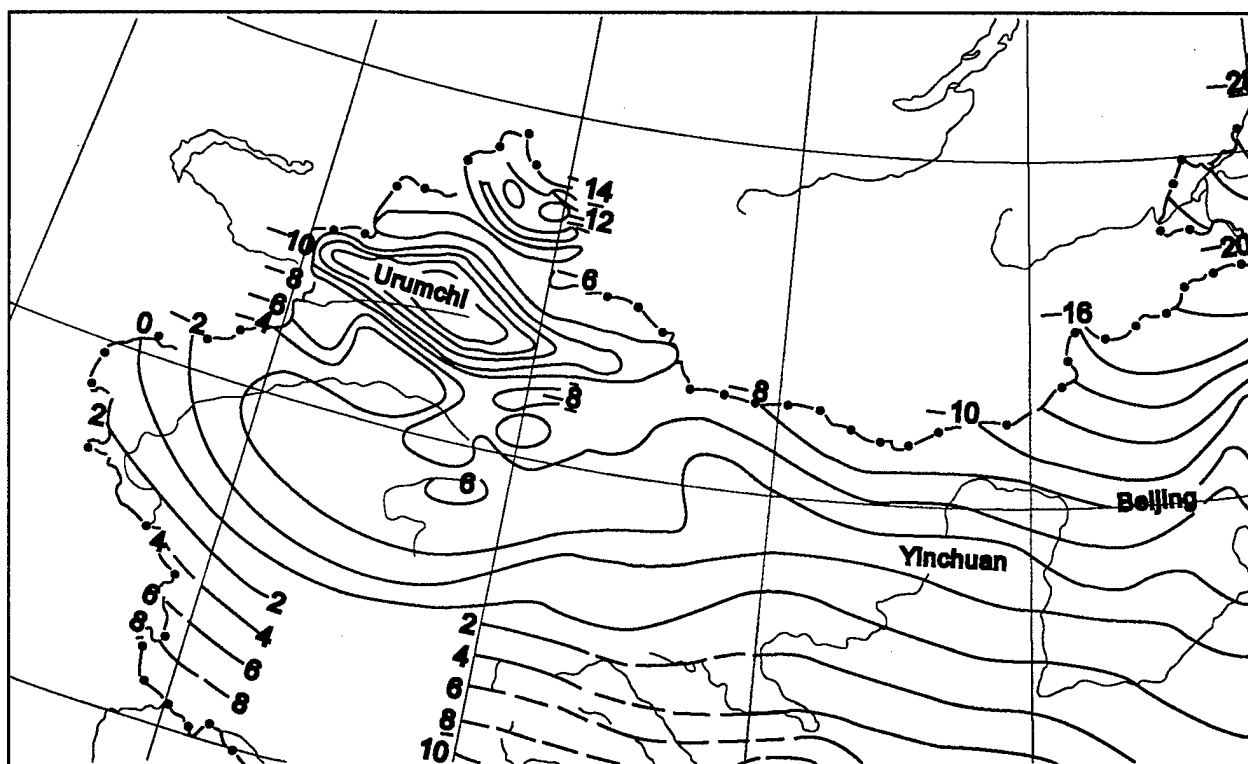


Figure 4-10. Stations Reduced to Sea-level Temperature (°C) against Heights of Station in Northern Xinjiang. This graph shows the shallowness of the Dzungarian basin cold-air pool. The dashed lines indicate extrapolated temperature data.

In fact, the mean January sea-level temperatures on the northern side of the Tien Shan are drastically colder than stations at comparative elevations on the southern side of the range. This effect is shown in Figure 4-11. The mean temperature difference of 14 Fahrenheit (7.9 Celsius) degrees per degree of latitude is significantly greater than the average of 3 Fahrenheit (1.5 Celsius) degrees per degree of latitude across the flat plains of northeastern China. The lowest recorded temperature across the region was -49°F (-45°C) at the city of Fuyun in the far northern Altai Mountains. Extreme lows from -23°F (-30°C) to -35°F (-37°C) can also be found at stations in the Tien Shan and Altai mountains. Erenhot, which is located in the northeastern corner of the Gobi Desert, has an extreme low temperature of -43°F (-41°C). Other stations in the vicinity have

recorded extreme lows of from -17 (-27°C) to -26°F (-32°C). The Tien Shan mountains, which serve as a barrier to Siberian air, modify extreme lows in the Tarim basin to the -3°F (-19°C) to -17°F (-27°C) range.

The extreme maximum temperature for January was 63°F (17°C) at Qiemo. Downslope winds from the Kunlun Shan Mountains adiabatically warm air on the southern periphery of the Tarim basin. Zhangye, which is located on the fringe of the northeastern Kunlun Shan and the Gobi Desert, has the second highest maximum temperature in the region 60°F (15°C). The lowest extreme maximum temperatures are found at Altai 38°F (3°C), Fuyun 40°F (4°C), and Karamay 40°F (4°C), all in the northern Tien Shan and Altai mountains.

Northern Stations	January Temperatures	Southern Stations	January Temperatures
Bole	-15.0	Yining	-6.5
Jinghe	-14.2	Nileke	-5.5
Wusu	-14.0	Xinyuan	-2.4
Jiersaer	-12.9	Turfan	-8.3
Qitai	-14.4	Shangshan	-8.3
Mean	-14.1	Mean	-6.2

Figure 4-11. Comparison of Sea-Level Temperature (°C) on the Northern and Southern Side of the Tien Shan Range. The Tien Shan Mountains effectively restrict the coldest air to the Dzungarian basin.

The diurnal temperature range, from 22 to 30 Fahrenheit (12 to 16 Celsius degrees), is greatest across the Tarim basin. The cold, clear, dry conditions in the desert allow for greater daytime insolation and enhanced nighttime radiation. Adiabatically warmed air parcels advect down the lee side (southern edge) of the Tien Shan Mountains, and deliver the exceptionally dry conditions favorable for a large diurnal variation. Logically, on the northern side of the Tien Shan, and in the mountains themselves, moister, cloudier conditions prevail. A smaller variation of 7 to 14 Fahrenheit (4 to 8 Celsius) degrees results. The cold, arid Gobi Desert also has a large mean daily temperature variation of from 18 to 23 Fahrenheit (10 to 13 Celsius) degrees. The reason this range is not quite as large as the variation for the Tarim basin, is the absence of the downslope winds for the nearby Tien Shan Mountains.

With the exception of the southern Tarim basin, mean maximum temperatures across northwest

China remain well below freezing. The lowest mean maximum temperatures are in the Altai Mountains and in the Dzungarian basin. Temperatures in these areas barely exceed 14°F (-10°C). The cold pool of air in the Dzungarian is clearly shown on Figure 4-12. The highest mean daily maximums only barely exceed 32°F (0°C) along the southern rim of the Tarim basin.

The cold pool of air in the Dzungarian basin is quite apparent in Figure 4-13. Only the Altai Mountains and the region which surrounds Erenhot, with a mean daily minimum of -4° to -13°F (-20° to -25°C), have colder mean daily minimums in winter. The warmest mean daily minimums are restricted to the extreme southwestern corner of the Tarim basin and the extreme southern tip of the Gobi Desert. Mean daily minimums in these areas average 14°F (-10°C). Mean daily minimums across the rest of northwest China are mostly isothermal and decrease poleward between 7° and -1°F (-14° and -18°C).

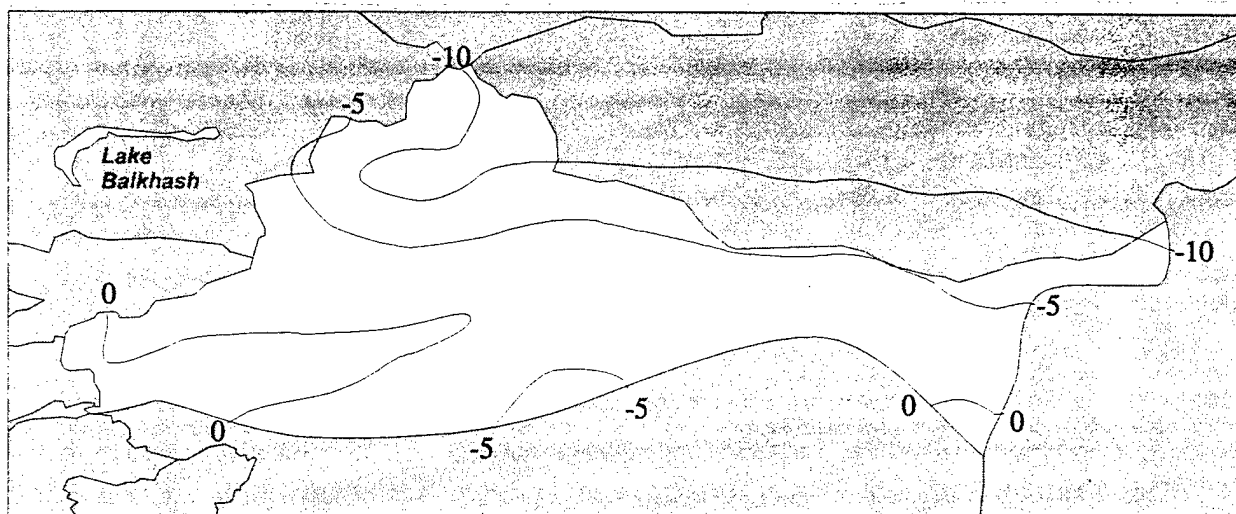


Figure 4-12. January Mean Maximum Temperatures (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

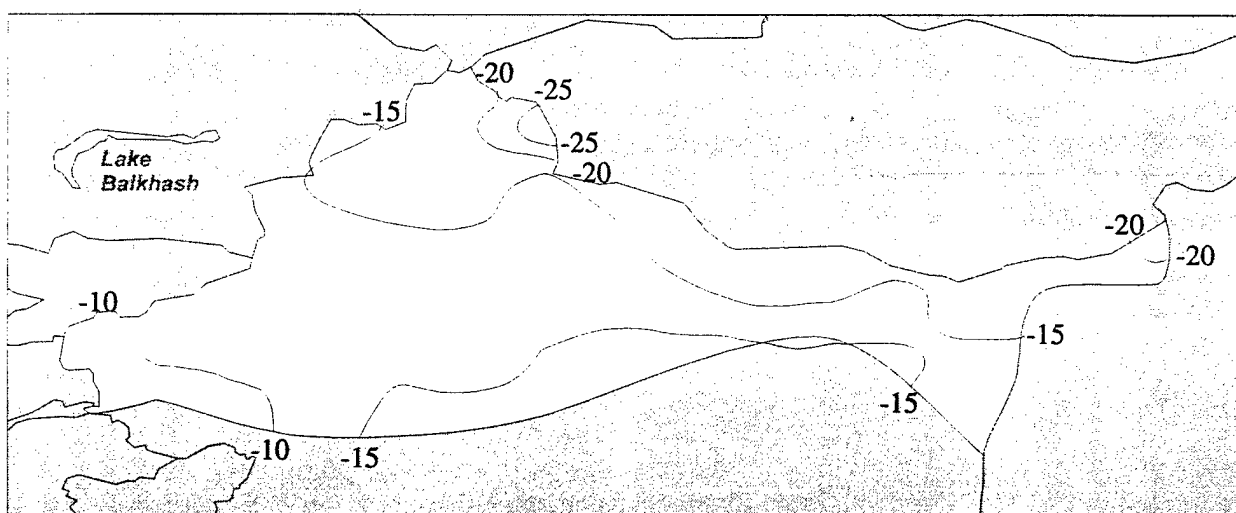


Figure 4-13. January Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

Hazards.

Aircraft Icing. Icing is mainly restricted to altocumulus and altostratus found in the migratory frontal systems that pass through the region from the distant Atlantic Ocean moisture source. Low-level moisture is normally too scarce to allow any more than a trace of icing. Light-to-moderate rime icing is found in the light but nearly continuous snowfall found over the Tien Shan and Altai mountains.

Turbulence. Strong post-frontal northerly winds, blowing perpendicular to the east-west oriented Tien Shan Mountains, produce conditions conducive to mountain-wave turbulence. With sufficient moisture available, altocumulus standing lenticular (ACSL) clouds will form on the lee side of the ridge line. Since the air is usually too dry, ACSL will not normally be present, but moderate-to-severe turbulence will still exist up to 45-60 miles (75-100 km) downstream and to an altitude of 45,000 to 95,000 feet (15 to 30 km).

The mountain wave usually breaks down on the second day after the frontal passage. The winds shift from a northerly direction to an easterly or southeasterly direction. Once the perpendicular component decreases, the mountain wave and the resulting turbulence dissipates. The peak time for mountain wave occurrence is from late winter into spring. This ties in with the weakening of the Siberian high and the opening of the storm track into northwest China.

Duststorms/Sandstorms. Duststorms and sandstorms can occur anytime during the year. The two primary factors required for duststorms/sandstorms are strong solar heating and mean wind speeds greater than 15 knots. The arid soil, along with sparse vegetation, make the deserts of Xinjiang, Gansu, and the Gobi prime areas for this phenomenon. During the 30 or more sandstorms that occur in the region each year, both dust and sand are lifted as high as 13,000 feet (4,000 meters) AGL. Visibility is restricted to near zero for usually 2 hours, but conditions can persist for as long as 24 hours.

Blowing dust and sand are the most common and are the most serious hazards to operations in northwest China. Dust is a finer, smaller atmospheric particle that is nearly always present in the deserts. Sand is a larger, more coarse particle that requires greater wind speeds to be lifted and transported. Additionally, stronger winds and longer trajectories will cause sand and dust particles to be lifted higher. Aircraft downrush raises dust and sand from the desert floor, reducing visibility in the immediate vicinity of the aircraft. Also, dust and sand enter engine intakes and cause damage. During severe sandstorm conditions, ablation of windscreens and other aircraft parts can occur. Persistent dust conditions also cause problems with dry skin, sore throat, and cracked lips. Dust also contributes to radio signal degradation. A heavy electrostatic discharge may result from the impact of windblown particles striking an object. The surprisingly high-voltage sparking associated with these electrostatic discharges can pose a hazard to personnel and equipment.

Trafficability. Desert areas of China are mostly flat to undulating sandy and gravelly plains. Some are broken by flat-bottomed ravines and rocky crests. The soils are predominantly sandy and vary in thickness from thin to very deep. In many places, shallow soils are covered by a layer of gravel or rock rubble. Some areas have dunes that vary in size and shape and extend up to 30 miles (50 km) in length. Conditions for movement are fair to very good on flat, gravelly plains. In areas with deep, sandy soil conditions are poor to unsuitable. In dune areas, movement is restricted to inter-dunal routes. Conditions in other areas of the desert are fair except in rough, dissected terrain and in areas of rock outcrops and bouldery surfaces.

Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadow, intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine grained, and consist of clays and silts. The soil type range, however, includes sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and intensive, man-made terracing. Conditions are fair to good in alpine meadows especially if frozen, and conditions are also fair to good in some valley bottoms.

NORTHWEST CHINA

Spring

April-May

General Weather. Spring in northwest China is a relatively short season. By April, the Siberian high disappears and the northern branch of the polar jet reforms over northwest China. Migratory frontal systems, no longer blocked by the Siberian high, enter from central Asia. Associated moisture is normally restricted to mid- and upper-levels by the time these systems, which originate in western

Europe, reach northwest China. For most of the region, the main weather impacts produced by these systems are blowing sand and dust. By the end of spring, the primary moisture source shifts from the Atlantic Ocean to the Arctic Ocean. Polar outbreaks that cross the low, flat terrain of western Siberia bring moisture directly through the Irtysh valley into the Dzungarian basin.

Sky Cover. By April, the extremely dry and stable conditions associated with this wintertime feature no longer characterize the air mass of northwest China. Frontal systems that were previously blocked or deflected by the Siberian high are now able to affect the region. These systems that bring in moisture from the distant Atlantic and Arctic oceans, also bring an increased amount of cloud coverage into northwest China. Total mean coverage increases from 40 percent in winter to between 50-60 percent in spring. Across northern Xinjiang, this increase is mostly found in the mid- and upper-cloud layers. Most stations in the Dzungarian basin and the Altai Mountains report ceilings below 3,000 feet less than 3 percent of the time. The greatest increase in coverage in the low cloud layer is found across the Tarim basin. For example, at Hotan, the amount of time ceilings below 3,000 feet are reported increases from less than 1 percent in January to more than 15 percent in April.

Across northern Gansu and the Gobi Desert, total mean cloud coverage remains less than 30 percent. Dunhuang, Ejinaqi, and Bayan Mod each report ceilings below 3,000 feet less than 1 percent of the time. This is no change from the total cloudiness found in the winter. Stations on the eastern edge of the Gobi Desert—Hailu, Hailu, and Mandal—report ceilings below 3,000 feet an average of 8-13

percent of the time. This is a considerable increase over the 1 percent of the time these low ceilings are reported in winter. The frequency of ceilings below 3,000 feet at selected locations across northwest China is depicted in Figure 4-14.

The dominant cloud type gradually changes from stratiform to cumuliform as spring progresses. The strong subsidence inversion previously found under the Siberian high is gone. High-based cumulus clouds that develop due to strong surface heating and a lack of low-level moisture, are the most common type of cloud found, especially in the vicinity of the mountains. These clouds, with bases between 4,000-6,000 feet and tops between 8,000-10,000 feet, form in the afternoon and normally dissipate after sunset. Only with the most dynamic fronts will this cumulus layer form a broken ceiling. Systems that enter from Kazakhstan and Siberia normally bring altocumulus with bases between 8,000-10,000 feet, and tops between 12,000-15,000 feet. This altocumulus deck may be capped by cirrus or cirrostratus clouds with bases between 20,000-25,000 feet, and tops extending to 30,000 feet. Altocumulus standing lenticular (ACSL) clouds occur within 1,000-2,000 feet above the ridgeline of mountain ranges during periods of strong winds that blow perpendicular to a ridgeline. Frontal systems rarely bring nimbostratus or stratus clouds.

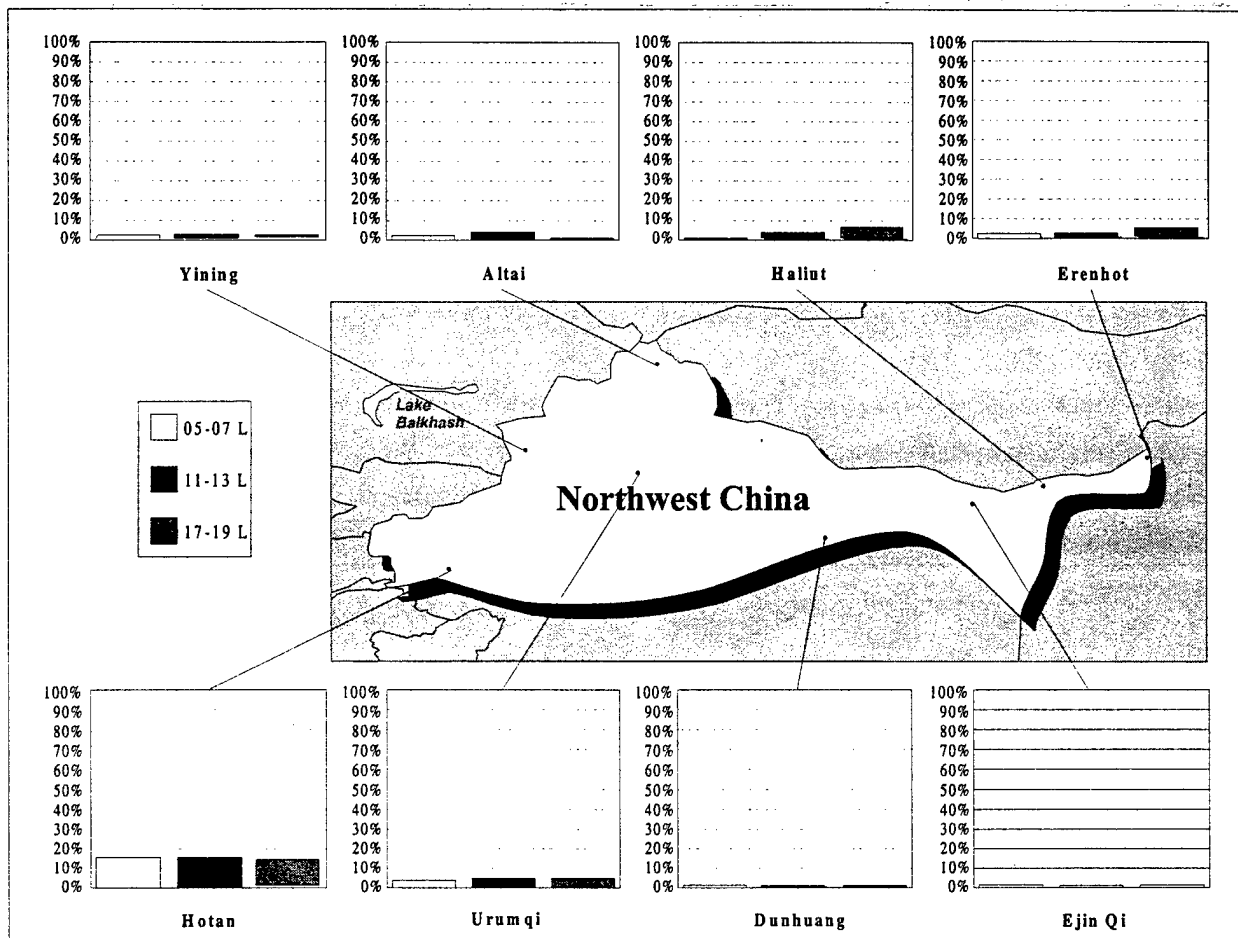


Figure 4-14. April Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Blowing sand/dust are the main causes of reduced visibility in the springtime. A higher frequency of more powerful frontal passages causes a rapid increase in the number of days when blowing sand/dust are reported. Blowing sand/dust reaches an annual maximum in spring, with the greatest frequency being reported in the Tarim basin. In particular, the stations on the southern rim of the Takla Makan Desert report the highest monthly average for blowing sand/dust of any region in China. For example, Hotan reports blowing sand/dust an average of 27 days during April and May. Additionally, these stations report the greatest occurrence of visibility below 4,800 meters in northwest China. Hotan, Minfeng, Andir, and Qiemo each report visibility below 4,800 meters between 30-40 percent of the time in the spring. Other stations in the Tarim basin report blowing sand/dust an average of 10-20 days a month in spring and visibility below 4,800 meters between 10-20 percent of the time.

The Gobi and Badain Jaran deserts have a much lower frequency of blowing sand/dust days than the Takla Makan Desert. Ejin Qi, Bayan Mod, and Hails each average only 7 days a month of blowing sand/dust. These stations record visibility below 4,800 meters less than 5 percent of the time. The disparity between the eastern

and western deserts is due to a combination of topography and soil composition.

The Takla Makan Desert is surrounded by the Tien Shan and Kunlun Shan mountain ranges. When soil particulates are lifted into the atmosphere, they tend to remain suspended, and cannot leave the enclosed Tarim basin. As a result, the soil composition has a higher percentage of finer particles. In contrast, the eastern Gobi and Badain Jaran deserts are open. Consequently, the finer particulates advected out of the region long ago. Therefore, the soil composition of the Gobi and Badain Jaran consists of a much more coarse granule than that found in the Takla Makan. A coarser and heavier particle requires a higher, more sustained wind speed to provide the lifting mechanism to reduce visibility.

To a much lesser extent, precipitation is another reason for degraded visibility in the mountain ranges. The precipitation type has changed from winter's stratiform and steady, to cumuliform and showery. Rainfall, and snowfall at the higher elevations, is not as persistent or as steady as during the winter. Stations in the Tien Shan and Altai mountain ranges report visibility below 4,800 meters less than 2 percent of the time. Figure 4-15 shows the frequency of visibility less than 4,800 meters at selected stations across northwest China.

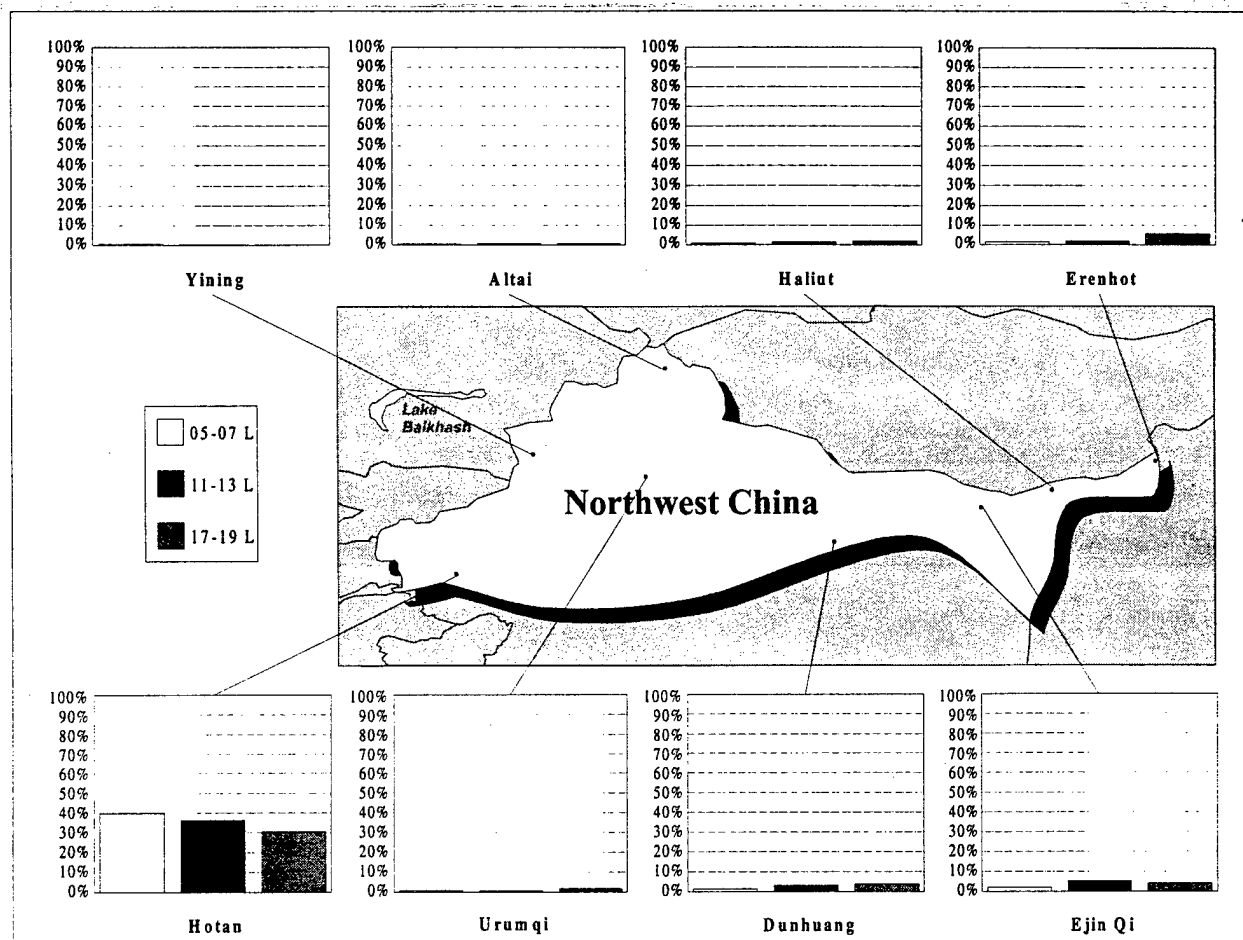


Figure 4-15. April Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Spring is the windiest time of year for most of northwest China. Without the stabilizing influence of the Siberian high, the region is returned to the control of the prevailing westerlies. Many stations record their extreme maximum wind speeds for the entire year during the spring months. Additionally, nearly every station reports an annual minimum of calm hours. Wind speeds across northwest China average between 6-12 knots but rarely drop below 5 knots. Stations located in the Tien Shan and Altai mountain ranges report wind speeds between 16-24 knots up to 5 percent of the time and wind speeds of between 25-34 knots 2 percent of the time. These higher wind speeds are even more common at sites located in northern Gansu Province and in the Gobi Desert. Ejinaqi records wind speeds in the 16-24 knot range nearly 20 percent of the time and between 25-34 knots almost 5 percent of the time. Hailuoguo records nearly the same frequency of wind speeds in the 16-34 knot range.

Localized terrain effects and mountain/valley breezes are still present, but to a much lesser extent. The prevailing westerlies and frontal passage winds play a much larger role in determining wind directions. For example, southerly drainage winds are still prominent at

Hailuoguo; however, the greatest percentage of winds in the 16-34 knot range are northwesterly. Xinjiang stations in the proximity of the Altai, Tien Shan, and Kunlun Shan mountain ranges still reflect a weak mountain/valley breeze effect. Most stations, however, reflect a greater propensity for a westerly component in their wind direction. Figures 4-16 and 4-17 show a breakout of late-night and midafternoon wind speeds and directions at selected locations across northwest China.

Gale force winds are defined as wind speeds that exceed 34 knots. The number of days when gale force winds occur in northwest China dramatically increases to 10-15 days per month in April and May. The higher end of this range occurs in the higher terrain of the mountains of Xinjiang, especially along the Sino-Mongolian border in northern Gansu Province and in the Gobi Desert. This is reflected by the extreme maximum wind speeds in these areas. The highest wind speeds recorded in northwest China occurred in these particular areas. For instance, a record of 66 knots was recorded at Yining, Kashi, and Karamay. A record of 62 knots was reported at both Mazong Shan and Erenhot, found at opposite ends of the Gobi Desert along the Sino-Mongolian border.

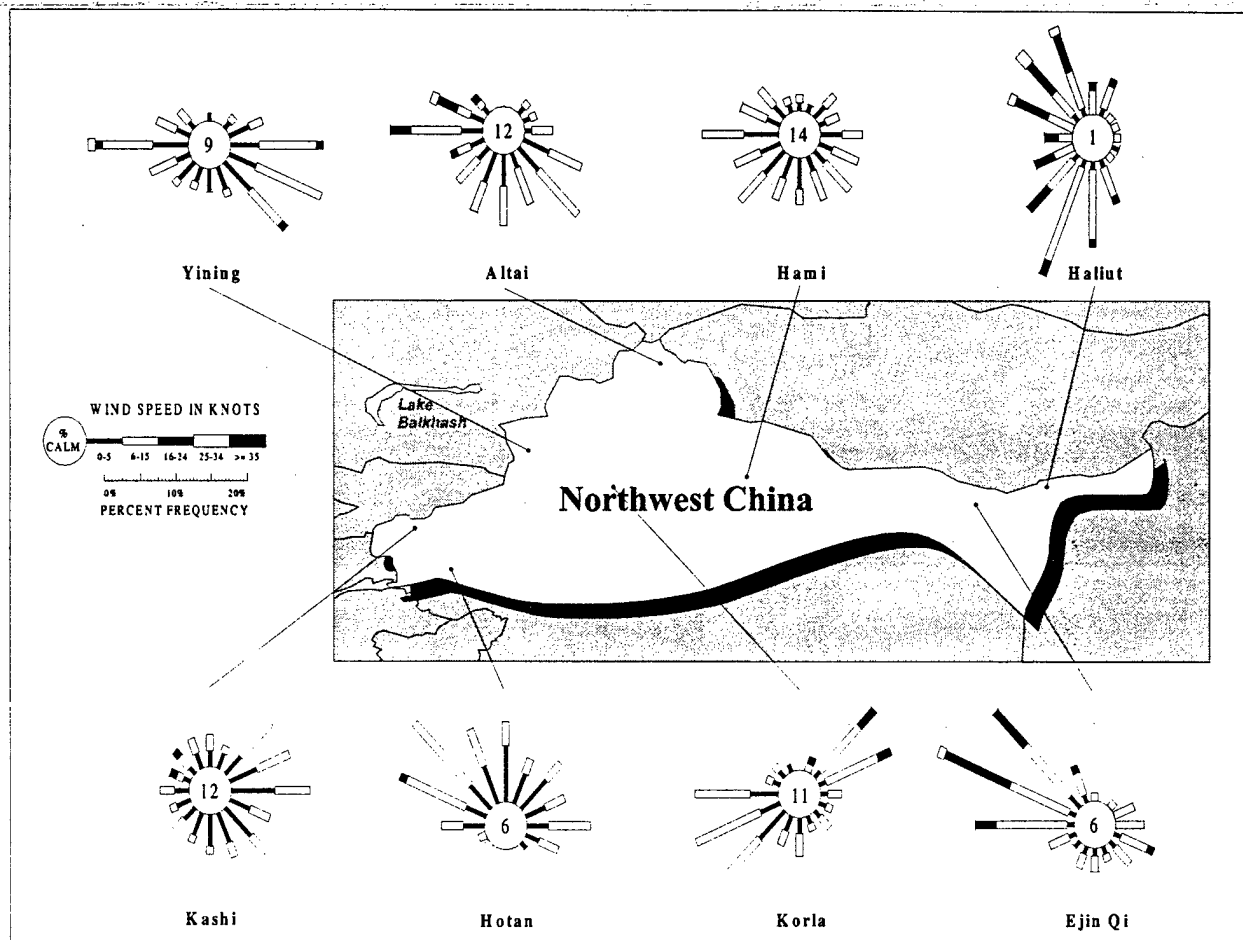


Figure 4-16. April 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on frequency and location.

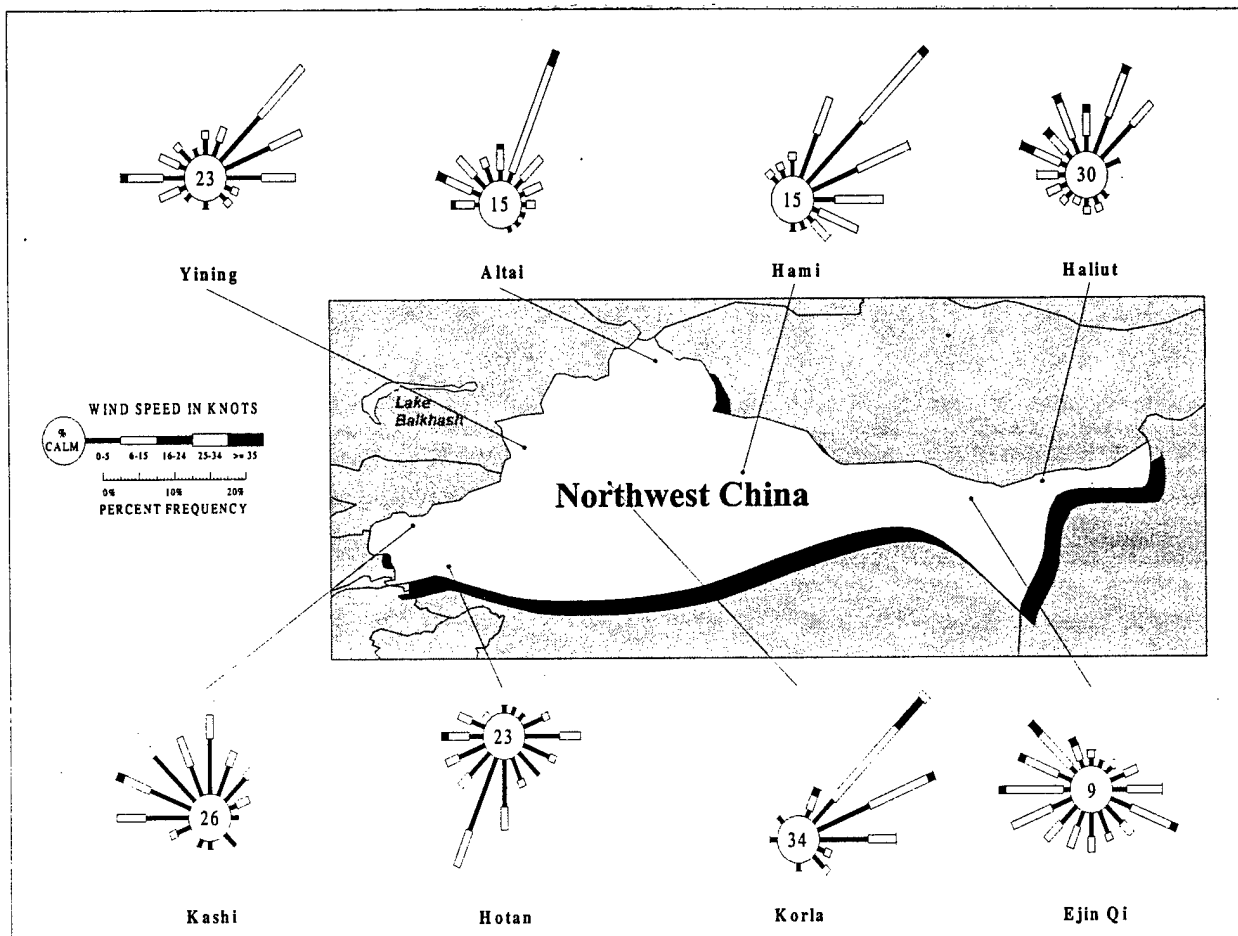


Figure 4-17. April 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on frequency and location.

Winds Aloft. The mean position of the polar jet extends east-southeastward along the Sino-Mongolian border before it merges with the subtropical jet over eastern China. The mean height of the jet stream is found at 200 mb. The average wind speed of the polar jet is between 50-75 knots. Wind speeds exceed 100 knots less than 2 percent of the time. Between 700 and 200 mb, the

predominant wind direction is west-northwesterly. The height of the Tien Shan, Altai, and Kunlun Shan mountain ranges greatly influences winds at the 850-mb level. Wind speeds at all levels are greatest the closer the station is to the mean jet position. Wind speeds correspondingly diminish at stations south and west of the jet. These effects are shown in Figure 4-18.

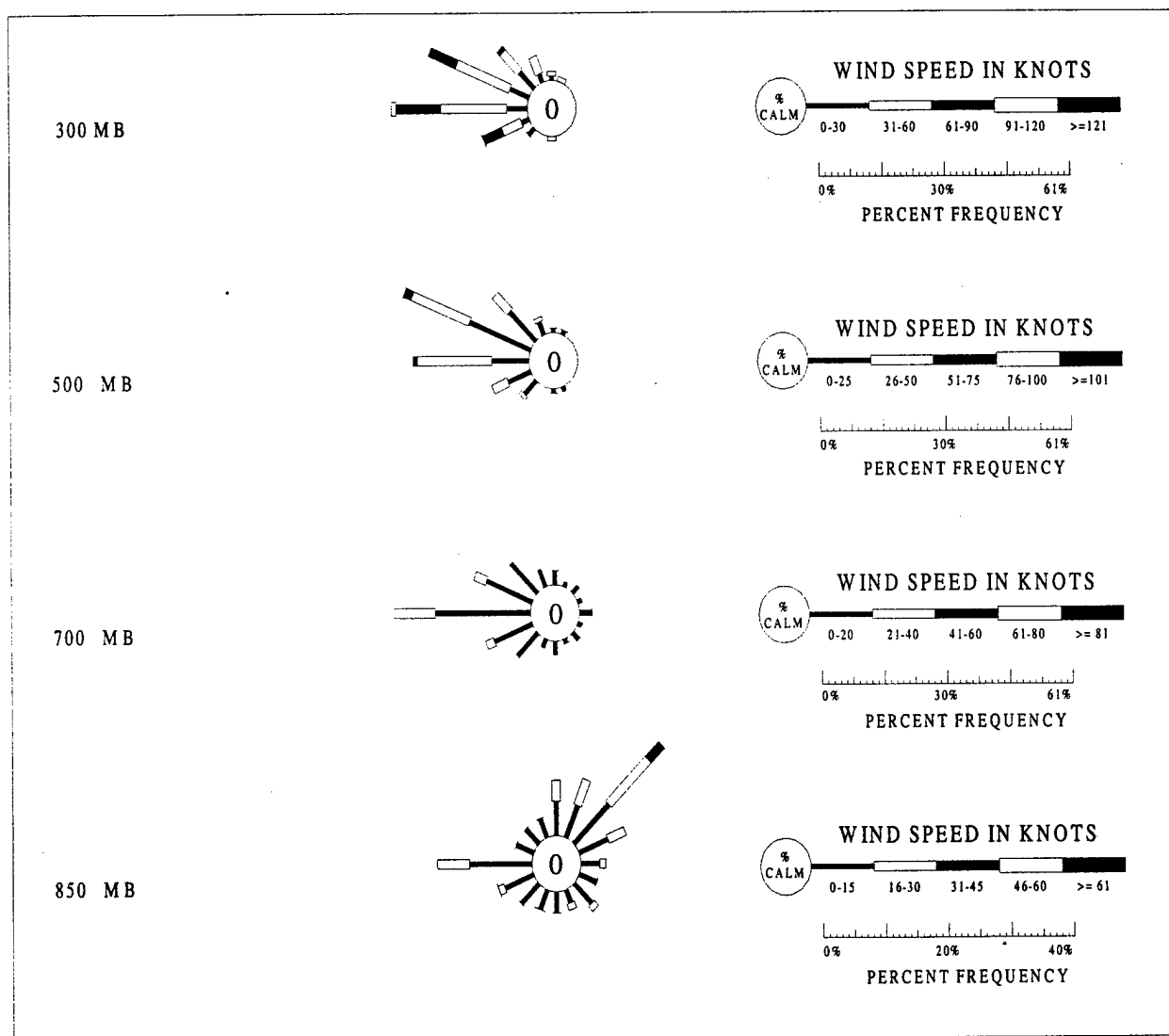


Figure 4-18. April Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Altai. Note: Each wind rose has a tailored legend.

Precipitation. While most of northwest China remains extremely arid, spring brings an increase in precipitation across the Dzungarian basin and the Tien Shan Mountains. The breakdown of the blocking Siberian high allows a greater frequency of moisture-laden frontal passages. The number of days with rainfall increases all across the region. Decreased stability across the region causes showery precipitation, rather than the steady type found in the winter season. Low-level moisture is able to filter through several passes in the northwestern Tien Shan Mountains to fall as rainshowers in the Dzungarian basin. This incursion of moisture frequently falls in the form of snow at higher mountain locations. Baytik Shan, at an elevation of 5,417 feet (1,651 meters) in the Altai Mountains, averages 9 snowfall days in April, 3 in May, and even 1 day of snowfall as late as June. The wettest spot in northwest China is the central Tien Shan Mountains, just west of Urumqi. During spring, an average of 150 mm of precipitation, mostly in the form of snow, is recorded. The majority of this precipitation falls in May. Urumqi, which is located in a lush valley on the northern

slopes of the Tien Shan, records an average of 70 mm of precipitation during the spring months. This location also records 3 snowfall days in April and 1 day with snowfall as late as May. This is in addition to the 9 days in April and 10 days in May when rainfall is reported. The Dzungarian basin averages more than 25 mm of precipitation in April and May—far more than the barren Tarim basin.

If the Tien Shan is the wettest part of northwest China, then the driest part in northwest China, by far, is the Turpan depression. The airport at Turpan reports less than a millimeter of precipitation for the entire spring season. The Takla Makan and Gobi deserts sometimes record no precipitation during spring. Each desert averages less than 5 mm of precipitation for April and May. Heavier monthly amounts, 10-25 mm, are reported at the oases along the rim of the Tarim basin, near the base of the Kunlun Shan and Tien Shan mountains. Similar amounts are reported at Dunhuang, Jiuquan, and Zhangye along the northern base of the Altun and Qilian mountain ranges. Figure 4-19 shows the mean precipitation recorded across northwest China.

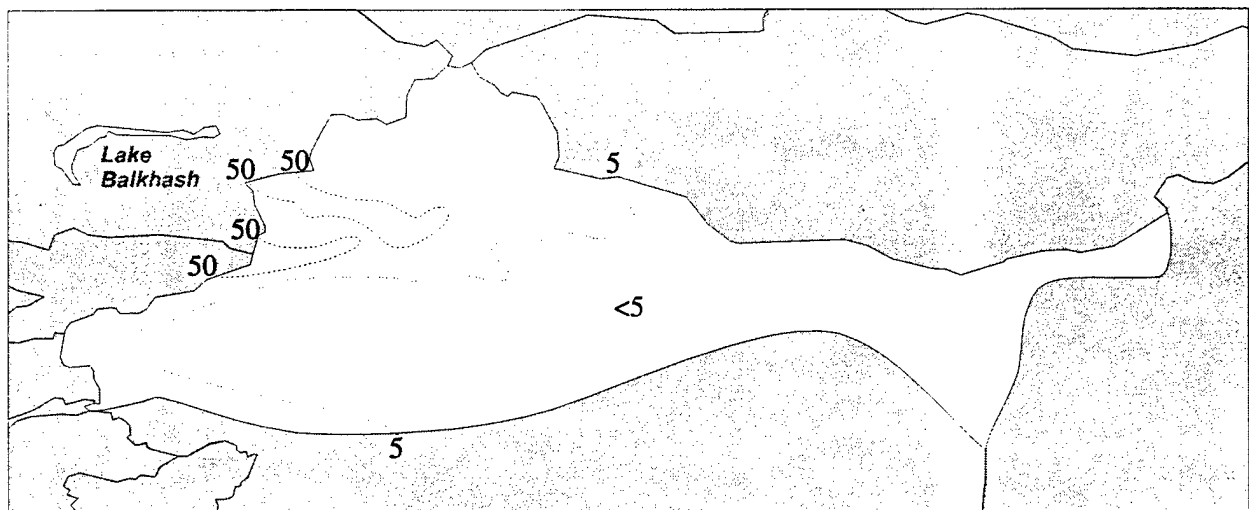


Figure 4-19. April Mean Precipitation (mm). The isopleths show the contrast between the amounts of precipitation recorded in the mountains and the deserts.

Temperatures. The vernal equinox brings much warmer temperatures to northwest China. Topography and elevation continue to play an important role in determining the mean temperature and diurnal variation of stations across the region.

The mean daily temperatures range from below 32°F (0°C) in the highest elevations of the Tien Shan Mountains, to 66°F (19°C) in the Turpan

depression. Across the Altai Mountains and the Dzungarian basin, the mean temperature ranges from 39°F (4°C) to 46°F (8°C). Also, the mean temperature is in the same range across northern Gansu and into the Gobi Desert. By contrast, the Tarim basin is outlined by the 54°F (12°C) isotherm, and the Takla Makan Desert is framed by the 61°F (16°C) mean isotherm. The mean temperatures across northwest China are depicted in Figure 4-20.

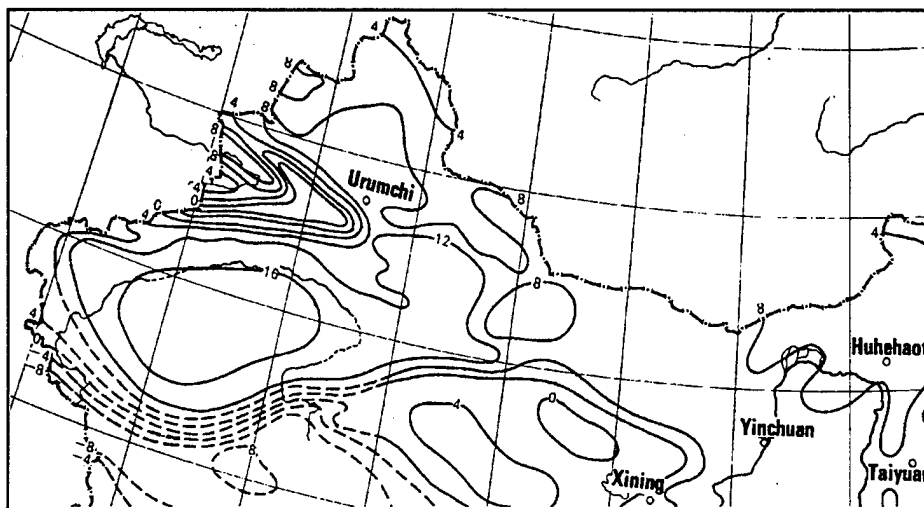


Figure 4-20. Mean April Temperatures (°C). The isopleths on this chart show the correlation between elevation and mean temperature. The dashed lines indicate extrapolated temperature data.

Spring

Diurnal variations across northwest China are influenced by moisture content in the atmosphere; the drier the area, the larger the diurnal variation. In the moist Dzungarian basin and the mountains of northern Xinjiang, the variation ranges from 16 to 22 Fahrenheit (9 to 12 Celsius) degrees. Across northern Gansu, and into the Gobi Desert, the diurnal variation ranges an average of 22 to 27 Fahrenheit (12 to 15 Celsius) degrees. In the Tarim basin, the diurnal variation ranges from 22 Fahrenheit (12 Celsius) degrees at Kashi along the western rim to 29 Fahrenheit (16 Celsius) degrees at Ruqiang and Dunhuang along the southeastern rim.

The lowest springtime temperature recorded in northwest China occurred at two separate locations. Both Baytik Shan (elevation 5,714 feet (1,651 meters)) in the Altai Mountains and Minfeng (elevation 4,626 feet (1,410 meters)) at the southern rim of the Tarim basin, near the base of the Kunlun Shan Mountains, recorded an April extreme minimum temperature of -8°F (-22°C). Undoubtedly, lower temperatures occurred but were not officially recorded at the highest elevations of the Tien Shan Mountains. The lowest temperature recorded in northern Gansu Province was -2°F (-19°C) at Mazong Shan (elevation 5,807 feet (1,770 meters)). In the Gobi Desert, the extreme minimum was 7°F (-14°C), recorded at Hails. Only Shache, Hotan, and Turpan have never recorded temperatures below freezing during the spring.

The record high springtime temperature, 109°F

(43°C), was recorded at the airport in Turpan. In the heart of the Turpan depression, the hottest place in China, even hotter temperatures have probably occurred, but since no one was there, they were not officially recorded. Hotan, located at the edge of the Takla Makan Desert, and at the southern rim of the Tarim basin, comes in second as the hottest place in China. Hotan recorded an extreme maximum for May of 108°F (42°C). In the Dzungarian basin, Karamay recorded a record high of 100°F (38°C). The record high for Urumqi, the capitol of Xinjiang Province, is 97°F (36°C). Dunhuang, with an extreme maximum of 102°F (39°C), holds the record for northern Gansu while Ejn Qi and Mandal share the record for the Gobi Desert with an extreme maximum of 100°F (38°C).

For the most part, mean daily maximum temperatures across northwest China are isothermal, and decrease with poleward progression. However, a very small area with mean daily maximums of 77°F (25°C) are restricted to the Turpan depression. The coldest mean daily maximums, 50°F (10°C), are restricted to a small area of the Altai Mountains. Figure 4-21 shows mean daily maximum temperatures for the most representative month in spring.

Only the extreme northern periphery of northwest China and the Kunlun Shan Mountains have mean daily minimums below freezing. The warmest mean daily minimums, 50°F (10°C), are restricted to the Turpan depression and the extreme southwestern corner of the Tarim basin. Figure 4-22 depicts the mean daily minimums for the most representative month of spring.

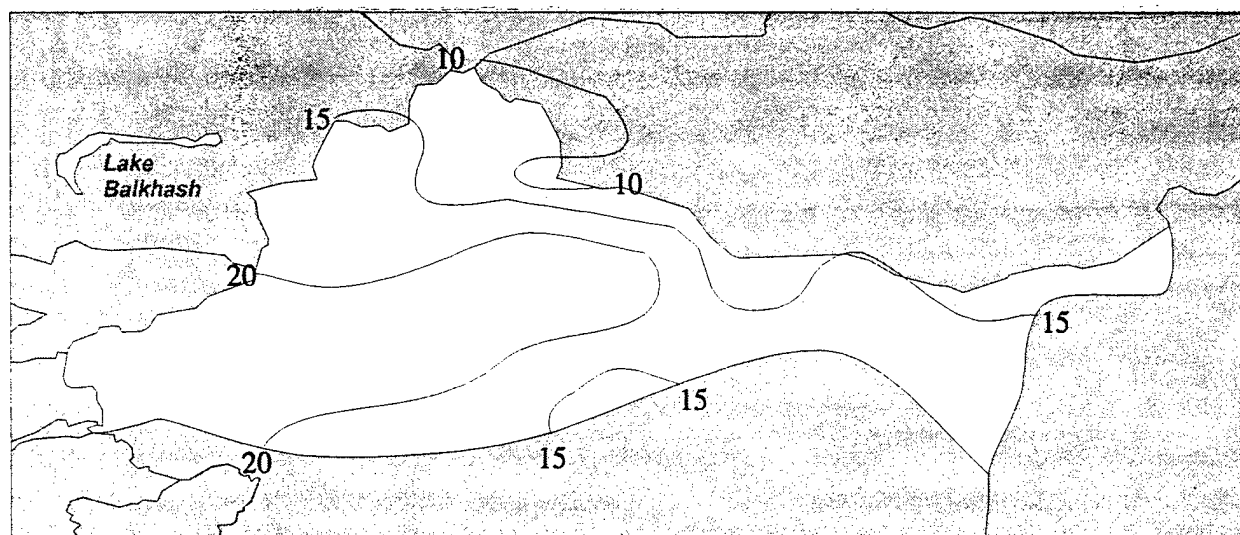


Figure 4-21. April Mean Maximum Temperatures (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

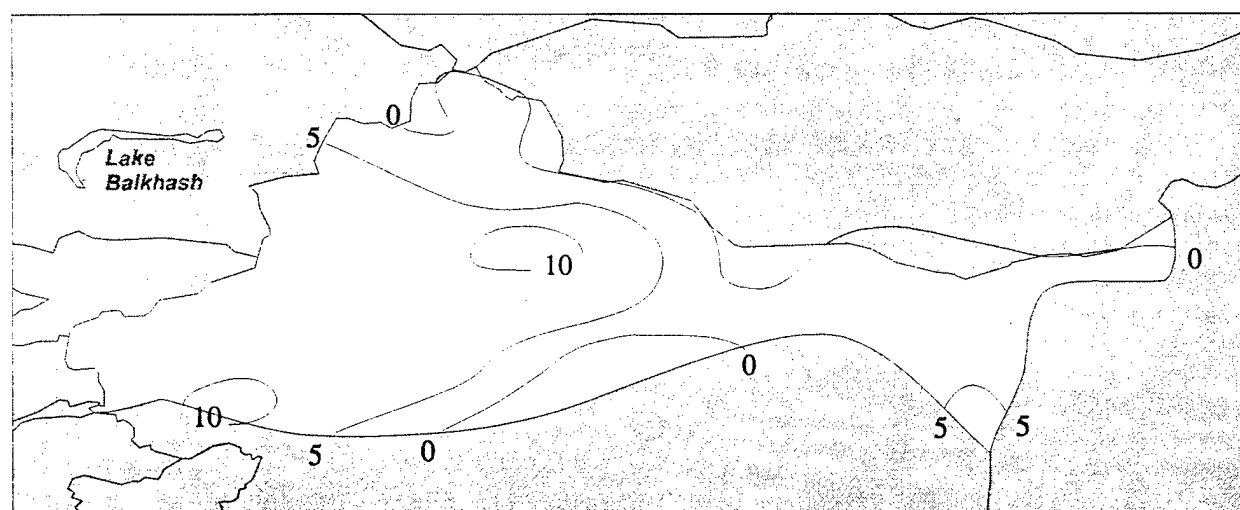


Figure 4-22. April Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

Hazards.

Aircraft Icing. Icing is mainly restricted to altocumulus and altostratus found in the migratory frontal systems that pass through the region from the distant Atlantic Ocean moisture source. Low-level moisture is normally too scarce to allow any more than a trace of icing. Light-to-moderate rime icing is found in the light but nearly continuous snowfall found over the Tien Shan and Altai mountains.

Turbulence. Strong post-frontal northerly winds, blowing perpendicular to the east-west oriented Tien Shan Mountains, produce conditions conducive to mountain-wave turbulence. With sufficient moisture available, altocumulus standing lenticular (ACSL) clouds will form on the lee side of the ridge line. Since the air is usually too dry, ACSL will not normally be visible, but moderate-to-severe turbulence will still exist up to 45-60 miles (75-100 km) downstream and to an altitude of 45,000 to 95,000 feet (15 to 30 km).

The mountain wave usually breaks down on the second day after the frontal passage. The winds shift from a northerly direction to an easterly or southeasterly direction. Once the perpendicular component decreases, the mountain wave and the resulting turbulence dissipates. The peak time for mountain wave occurrence is from late winter into spring. This ties in with the weakening of the Siberian high and the opening of the storm track into northwest China.

Duststorms/Sandstorms. Duststorms and sandstorms can occur anytime during the year. The two primary factors required for duststorms/sandstorms are strong solar heating and mean wind speeds greater than 15 knots. The arid soil, along with sparse vegetation, make the deserts of Xinjiang, Gansu, and the Gobi prime areas for this phenomenon. During the 30 or more sandstorms that occur in the region each year, both dust and sand are lifted as high as 13,000 feet (4,000 meters) AGL. Visibility is restricted to near zero for usually 2 hours, but conditions can persist for as long as 24 hours.

Blowing dust and sand are the most common and are the most serious hazards to operations in northwest China. Dust is a finer, smaller atmospheric particle that is nearly always present in the deserts. Sand is a larger, more coarse particle that requires greater wind speeds to be lifted and transported. Additionally, stronger winds and longer trajectories will cause sand and dust particles to be lifted higher. Aircraft downrush raises dust and sand from the desert floor, reducing visibility in the immediate vicinity of the aircraft. Also, dust and sand enter engine intakes and cause damage. During severe sandstorm conditions, ablation of windscreens and other aircraft parts can occur. Persistent dust conditions also cause problems with dry skin, sore throat, and cracked lips. Dust also contributes to radio signal degradation. A heavy electrostatic discharge may result from the impact of windblown particles striking an object. The surprisingly high-voltage sparking associated with these electrostatic discharges can pose a hazard to personnel and equipment.

Trafficability. Desert areas of China are mostly flat to undulating sandy and gravelly plains. Some are broken by flat-bottomed ravines and rocky crests. The soils are predominantly sandy and vary in thickness from thin to very deep. In many places, shallow soils are covered by a layer of gravel or rock rubble. Some areas have dunes that vary in size and shape and extend up to 30 miles (50 km) in length. Conditions for movement are fair to very good on flat, gravelly plains. In areas with deep, sandy soil trafficability is poor to unsuitable. In dune areas, movement is restricted to inter-dunal routes. Conditions in other areas of the desert are fair except in rough, dissected terrain and in areas of rock outcrops and bouldery surfaces.

Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins,

hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadow, intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine grained, and consist of clays and silts. The soil type range, however, includes sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and intensive, man-made terracing. Conditions are fair to good in some alpine meadows especially if frozen, and conditions are also fair to good in some valley bottoms. During the wet season, movement is virtually impossible except along established routes and locally in valley bottoms where coarse-grained soils may exist.

General Weather. Northwest China, as well as most of central Asia, is under the influence of the Pakistani heat low (mean center: 31° N, 68° E). This is a time of great heat across the deserts of the region. Afternoon thunderstorms are commonly found near the mountain tops. Even though precipitation is sparse, most stations record a large majority of their annual rainfall during the summer. The Azores high, now at its northernmost position (37° N, 37° W), imports the most moisture of any

time of the year into the area. Additionally, low-level moisture from the Arctic Ocean continues to enter the Dzungarian basin through the Irtysh valley. The abundant southwest monsoon moisture over the Indian subcontinent is cutoff from northwest China by the Tibetan Massif. The subtropical jet has migrated across the northern fringes of the region around the periphery of the Tibetan 200-mb anticyclone.

Sky Cover. The Tarim basin and the northern section of Gansu Province average the lowest mean amount of cloud cover of any region in China. This region produces a mean of only 10-30 percent cloud cover (scattered conditions) for the entire summer. Hotan averages only 3 percent coverage of low clouds. It is not uncommon for several years to pass between occurrence of any low clouds at these locations. Total and low cloud coverage is slightly higher across the Dzungarian basin and the mountain ranges of northern Xinjiang Province. The polar jet and the primary storm track is displaced into southern Siberia. Southern ends of passing migratory systems drag mostly mid- and high-level cloudiness into the Dzungarian basin area. Exceptionally dynamic systems also account for mid- and high-level cloudiness in the Tarim basin and the Gobi Desert.

Cloud types that occur over the region during summer are almost exclusively of the cumuliform variety. Cumulus clouds over desert regions, when they do occur, are normally only scattered and form with extremely high bases. It is not uncommon for cumulus to form at 8,000 feet in the afternoon. The tops of the cumulus only extends about 1,000 feet or so above that. In the Dzungarian basin, cumulus clouds are much more common than in the Takla Makan and Gobi deserts. As a function of the low-level relative humidity, the cloud bases form anywhere between 4,000 and 6,000 feet. Mountain tops in the Tien Shan, Altai, and Kunlun Shan ranges are obscured nearly every

afternoon by cumulus and cumulonimbus. Cumulonimbus clouds normally form as a result of mechanical lift over ridgelines and can get as high as 40,000 feet (12 km). These thunderstorm clouds generally remain over the mountains through the afternoon, but they can move over the deserts if the steering flow is strong enough. Without the orographic lifting mechanism provided by the mountains, they quickly fall apart.

Most stations in the region report ceilings below 3,000 feet less than 2 percent of the time. Only a few stations report these ceilings more than 5 percent of the time. The three stations in the northeastern Gobi Desert—Hails, Haliut, and Mandal—report the greatest frequency of ceilings below 3,000 feet. These stations report these ceilings up to 32 percent of the time. This abnormality is tied to topography, prevailing windflow, and time of day. These three locations are located at elevations between 3,900 and 4,900 feet on the northern (upslope) side of the Yin Mountains. The gap in the mountains just to the south of Haliut feeds low-level moisture from the flooded Huang (Yellow) River delta on the southern side of the mountains. Intense solar heating supports cloud formation in the afternoon over the desert. These clouds build until sunset when they collapse and dissipate. The development of ceilings coincides with the collapse of the afternoon clouds. Figure 4-23 depicts the frequency of ceilings below 3,000 feet at selected locations across northwest China.

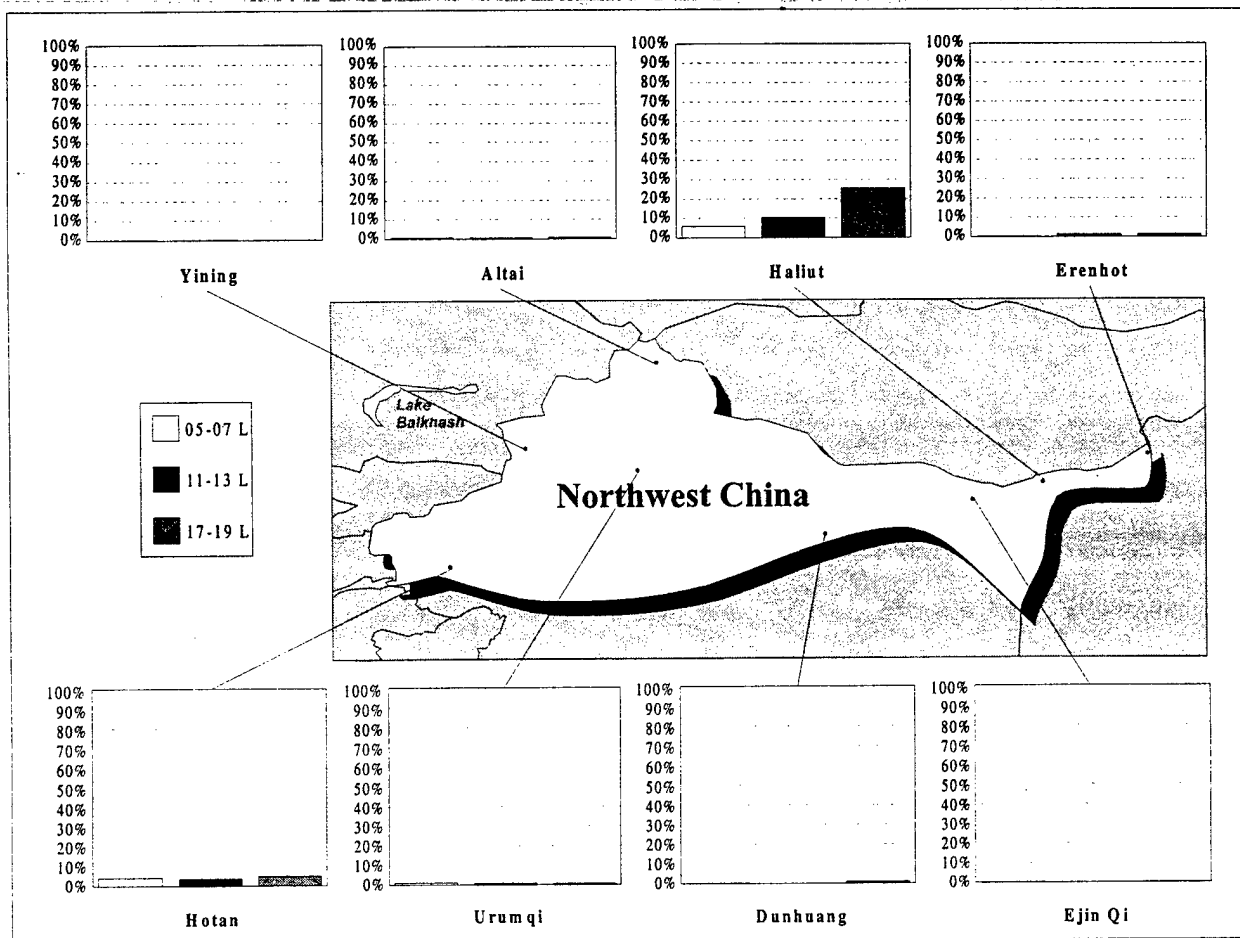


Figure 4-23. July Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. For most of northwest China, summer is the best season of the year for visibility. Most locations report visibility below 4,800 meters less than 1 percent of the time. Figure 4-24 shows the rarity of restricted visibility across northwest China. Even in the brief and infrequent rainshowers, visibility remains excellent. Fog is nearly nonexistent; only sites near mountains record an average of 1-3 days with fog during the entire season. The only part of northwest China where

visibility is a problem is along the southern rim of the Tarim basin. The prevailing northwesterly winds lift the fine dust and sand from the Takla Makan Desert to heights as high as 13,000 feet (4,000 meters). At the eastern and western ends of the southern rim, Ruoqiang and Kashi report visibility below 4,800 meters about 5 percent of the time. This average increases at sites along the rim until it reaches a peak in the center. Minfeng reports visibility below 4,800 meters up to 54 percent of the time at certain hours of the day.

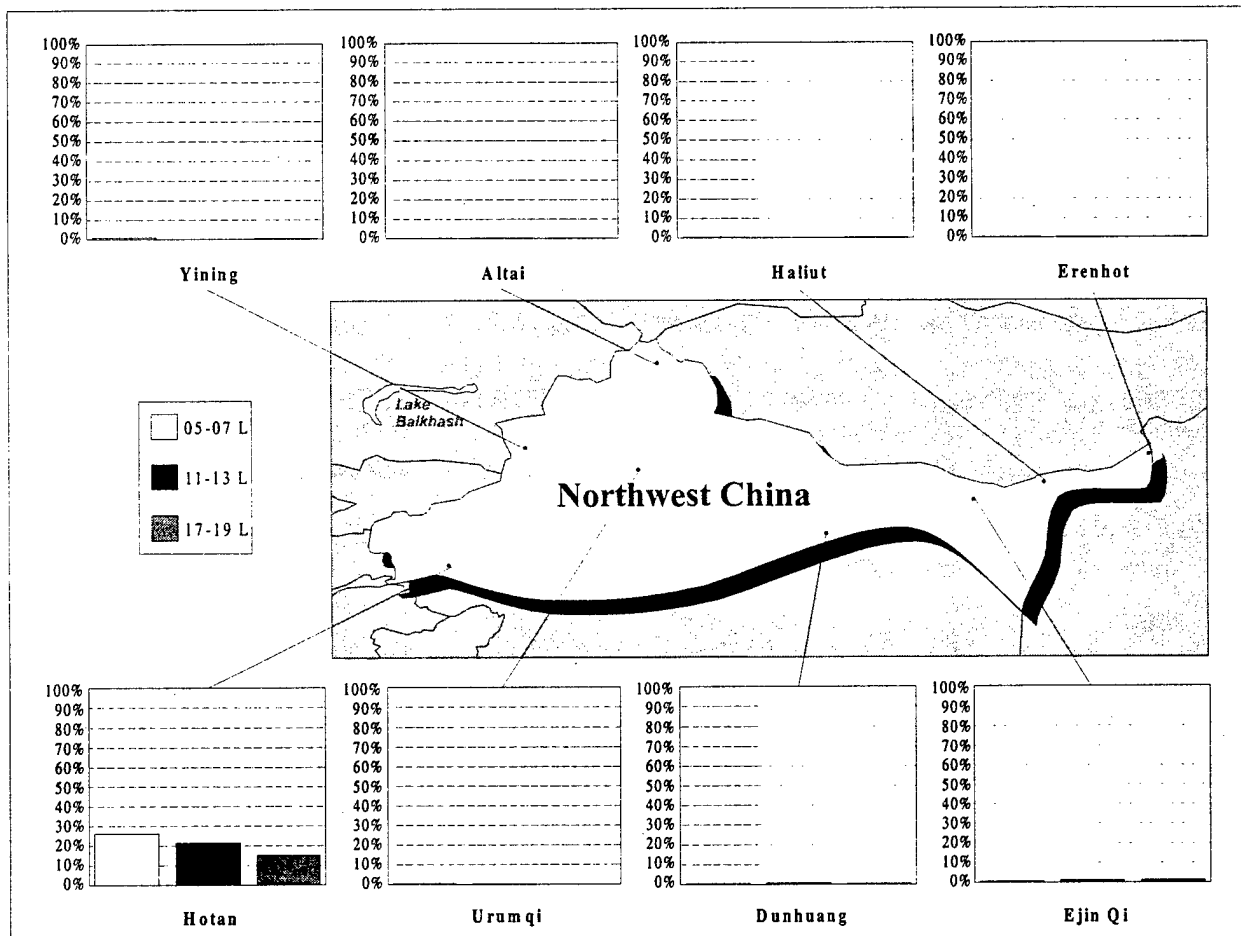


Figure 4-24. July Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. During summer, the wind direction is governed by the position and strength of the Pakistani low, but is highly influenced by terrain effects. Also, the polar jet and its associated storm track have a mean position at the northern fringe of the area. At many locations in mountainous regions, mountain/valley breeze effects are still present, although not quite as prominent as in the transition seasons. In particular, Yining receives a nighttime northeasterly mountain breeze from the Borohoro Mountains, a spur of the northern Tien Shan Mountains. Korla, displays a propensity for both afternoon and nighttime northeasterly winds. This is attributed to the mountain pass in central Tien Shan just to the northeast of Korla. The provincial capital of Urumqi is located on the northern end of this pass. Hotan, on the southern rim of the Tarim basin, shows a definite shift in wind direction from nighttime to afternoon. In the afternoon, Hotan experiences a generalized northwesterly flow that shifts to southwesterly in the night. The Kunlun Shan Mountains exceed 5,000 meters just to the south of Hotan. The wind flows down the Korokax and Yurongkax river valleys at night; Hotan lies directly in the path. Afternoon and late night wind speeds and directions are contrasted in Figures 4-25 and 4-26.

A distinct mountain breeze effect is obviously what is also occurring at Hami. During the day, no

definite wind direction is favored. Afternoon wind speeds are almost always below 15 knots and calm winds occur an average of 30 percent of the time. Night observations depict a different scenario, altogether. Figure 4-29 shows a mountain breeze from the large hills at the extreme end of the Tien Shan to the northeast of the station. Northeasterly winds occur more than 40 percent of the time with wind speeds of 6-15 knots a full 20 percent. No other wind direction occurs more than 5 percent of the time. Additionally, the frequency of calm winds drops to an average of 20 percent of the time. Finally, Haliut still displays a definite southerly to south-southwesterly wind coming from the gap in the Yin Mountains to the south of the station. This afternoon wind advects moisture into the desert and plays a strong causative role in the high frequency of low ceilings in the northeastern Gobi Desert.

The highest recorded summer wind speeds occurred in the Tarim basin. Korla reported an extreme maximum wind speed of 62 knots. Close behind this record is the 60 knots recorded at Qiemo and the 58 knots recorded at Kashi, Andir, Hotan, and Turpan. Haliut recorded 58 knots, and holds the seasonal record for the highest maximum wind speed recorded in the Gobi Desert. Finally, Hoboksar, in the northwestern part of the Dzungarian basin, also recorded an extreme maximum of 58 knots.

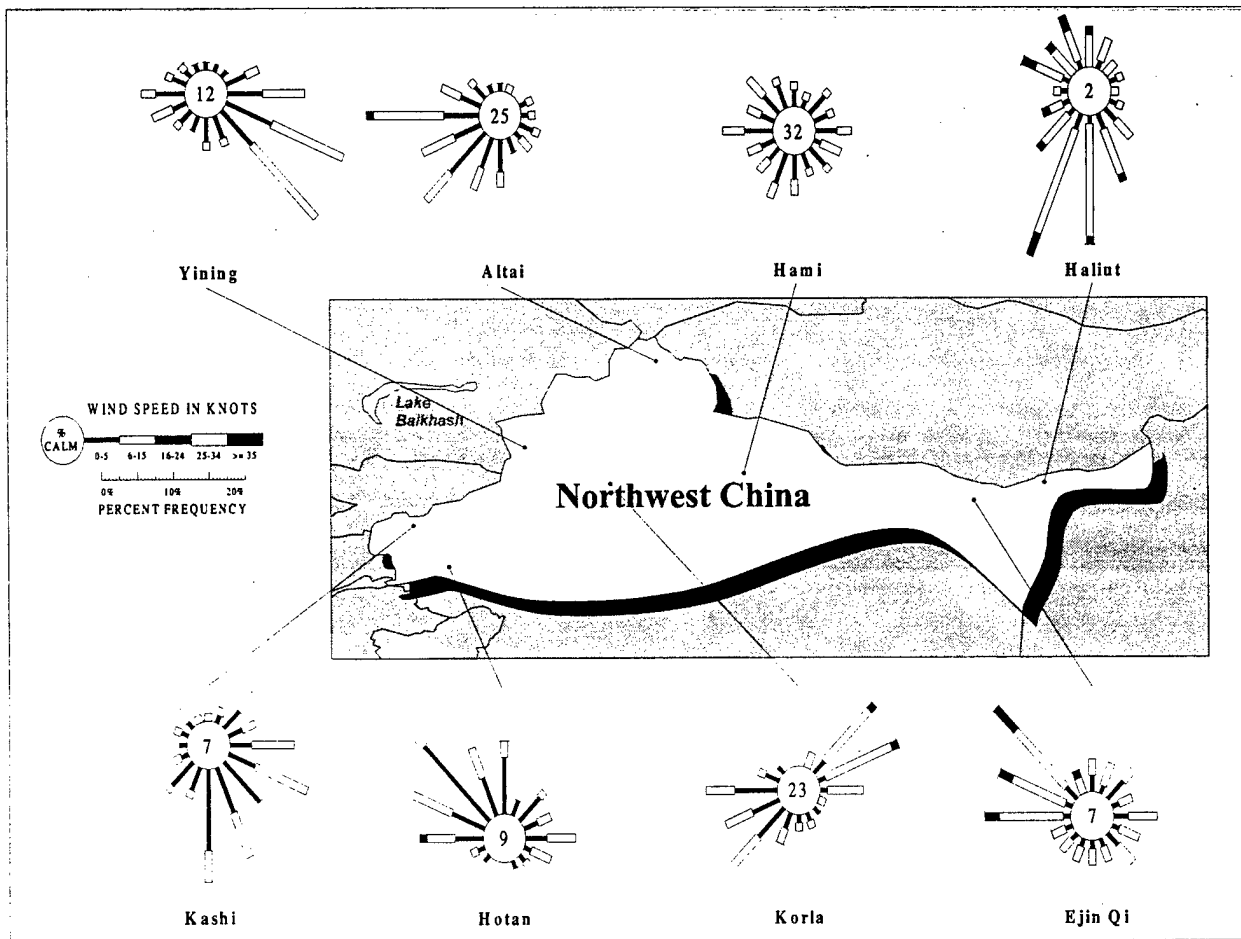


Figure 4-25. July 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on frequency and location.

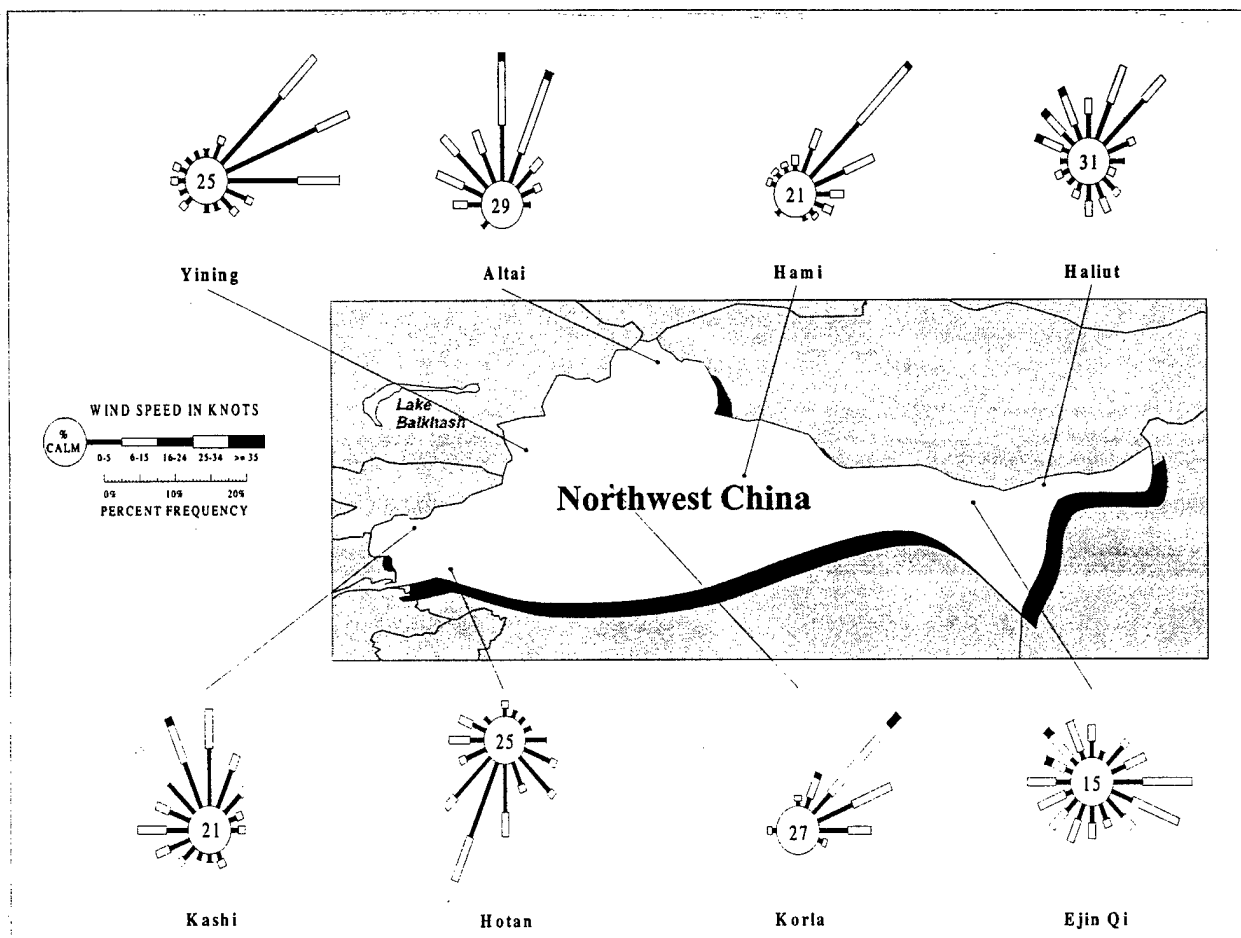


Figure 4-26. July 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on frequency and location.

Winds Aloft. The subtropical jet, at its northernmost mean annual position, enters Xinjiang Province across the northern Tien Shan Mountains. The jet then travels southeast over the Turpan depression before turning east along the Sino-Mongolian border. The subtropical jet, best

represented at the 200-mb level, has average wind speeds of 50-60 knots in the jet core. Wind speeds exceed 90 knots less than 2 percent of the time. The subtropical jet quickly shifts south of the Himalayas as the Tibetan Plateau 200-mb anticyclone weakens. Wind speeds and directions between 850 and 300 mb for Altai are depicted in Figure 4-27.

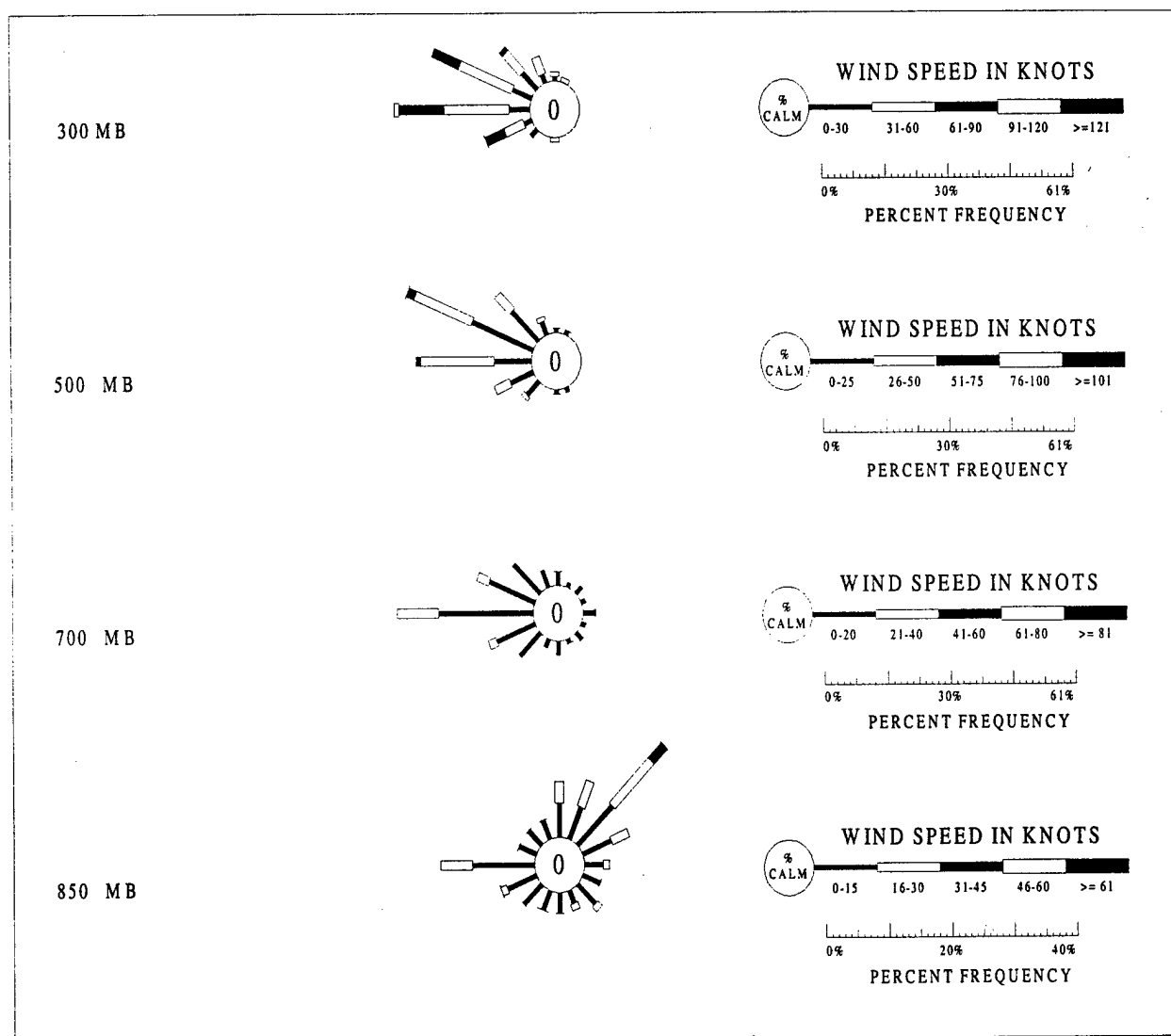


Figure 4-27. July Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Altai. Note: Each wind rose has a tailored legend.

Precipitation. Summer is the season with the most abundant amount of precipitation for most locations in northwest China. With the exception of a few places in the Tien Shan Mountains, rainfall totals and the number of days with rainfall reach an annual maximum. Figure 4-28 shows the relation between elevation and rainfall amounts. Even though the region is far from the Pacific and effectively blocked from the southwest monsoon by the Tibetan Plateau, the stations along the rim of the Tarim basin and the Gobi Desert record between 60-70 percent of their annual rainfall totals during summer. The predominantly northwestern windflow advects moisture into the region from both the Arctic and Atlantic oceans. Higher precipitation amounts result from orographic lift in mountainous terrain; however, the blistering temperatures in the deserts also provide effective trigger mechanisms for afternoon cumulus cloud development. The extreme surface temperatures, combined with low-level relative humidity, cause high-based cumulus and cumulonimbus to be formed. Most precipitation falling from these clouds evaporates before reaching the ground. This results in a high incidence of virga.

Even though rain occurs between one-third and one-half of the days in July and August, rainfall totals are still low compared to stations in the rest of China. With the exception of a few places in the Tien Shan Mountains, the extreme one-day rainfall for most places in northwest China is less than 75 mm. This is even below the threshold for moderate rain; a fairly common occurrence in other parts of China during the southwest monsoon. In fact, for most locations in the Tarim basin, a single rain event may account for a large percentage of the annual total. In extreme cases, a single rainfall may total several times the annual average. For example, Turpan normally averages 16.6 mm of precipitation annually. In a 12-hour period on August 14, 1958, Turpan recorded 36 mm of rain, more than 2 years worth of precipitation. On July 22, 1968, Qiemo received 42.9 mm of rain (more than 2.5 years worth), in just over 19 hours. A single downburst dumped 73.5 mm of rain (four times the annual mean) on Ruoqiang, on July 5, 1981. These rare downbursts can cause flash flooding and can also briefly fill the dry riverbeds that traverse the Tarim and Dzungarian basins.

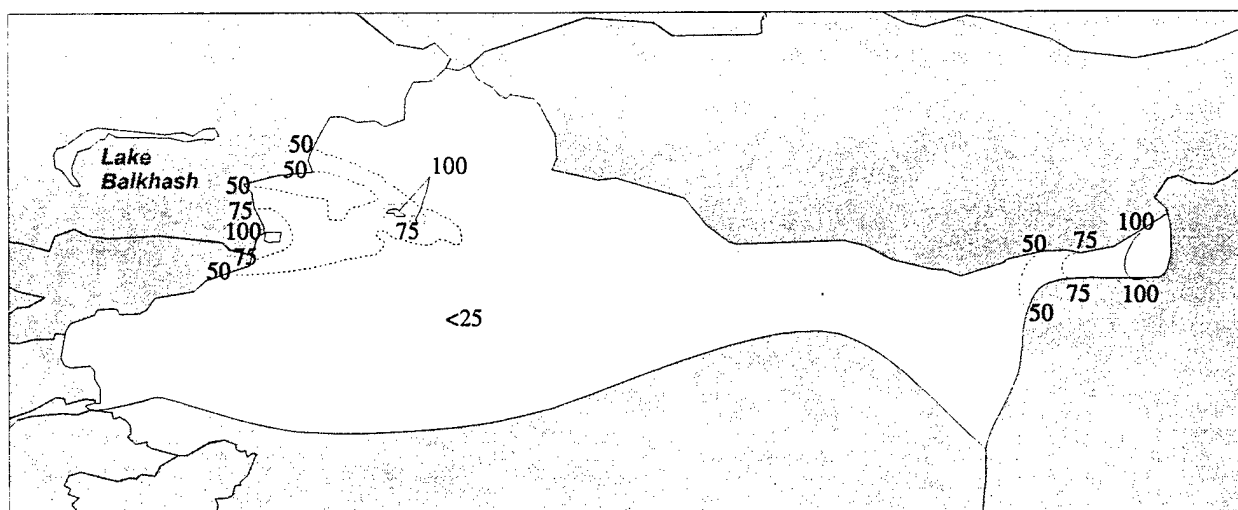


Figure 4-28. July Mean Precipitation (mm). The isopleths show the contrast between the amounts of precipitation recorded in the mountains and the deserts.

Thunderstorms. The mean number of thunderstorms reaches an annual peak during the summer. Nearly every location in northwest China records at least 90 percent of their thunderstorms during July and August. The general lack of low-level moisture makes thunderstorm activity rare in the desert regions; any cumulus or cumulonimbus clouds that do form are usually high-based. Virga is a frequent by-product of desert thunderstorms. Orographic lift is normally sufficient to produce thunderstorms in the mountains. The rare desert thunderstorms require more dynamic support than just intense surface heating. In the Takla Makan and Gobi deserts, thunderstorms require the incursion of low-level moisture along with the upper-level support of a migratory system. Thunderstorms occur almost exclusively during the late

afternoon. Maximum heating acts as a trigger mechanism. After sunset, desert thunderstorms quickly dissipate. Mountain thunderstorms can remain in the mature stage several hours longer.

The highest frequency of thunderstorms occur in the western Tien Shan Mountains. Between 50 and 60 thunderstorms occur annually in the mountains near the border with Kyrgyzstan and Kazakhstan. The area with the second highest frequency is in the Altai Mountains. Up to 35 thunderstorms occur each year along the border with western Mongolia. Annually, less than 10 thunderstorms occur in the Gobi Desert and less than five occur in the Takla Makan Desert. Figure 4-29 shows the mean number of thunderstorm days at selected locations across northwest China.

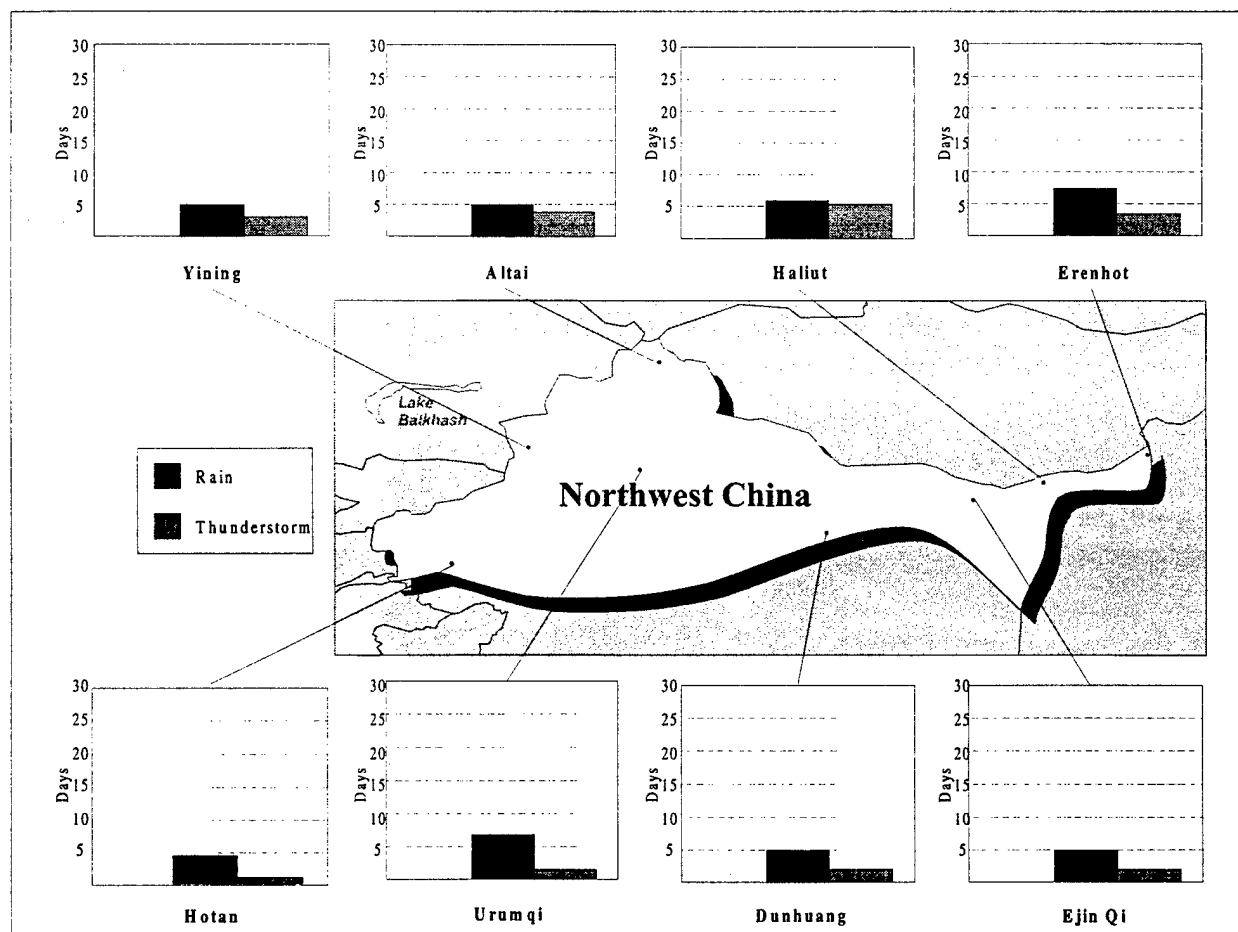


Figure 4-29. July Mean Number of Rain and Thunderstorm Days. The graphs show the number of days with thunderstorms based on average occurrences at selected locations in northwest China.

Temperatures. In summer, the deserts of northwest China are some of the hottest places on the face of the earth. The barren wastelands of the Takla Makan and the Gobi deserts are far removed from any source of moisture. Temperatures in the deserts normally rise rapidly after sunrise, sometimes by as much as 9 to 13 Fahrenheit (5 to 7 Celsius) degrees per hour in the morning. The afternoon maximum is usually reached by 1500L. As soon as the sun goes down, however, the dry air mass is unable to hold any appreciable heat, and the temperature plummets.

Low atmospheric moisture content creates a large diurnal variation across the region. The mean diurnal variation between the daily minimum and maximum temperatures is as large as 27 Fahrenheit (15 Celsius) degrees in the southern Takla Makan Desert. With more moisture available in the Dzungarian basin, the Tien Shan

and Altai mountains, the mean diurnal variation is usually only between 16 and 22 Fahrenheit (9 and 12 Celsius) degrees. The true arid nature of the deserts is reflected in the range between summer extreme high and low temperatures. Many stations in the region have a range of at least 72 Fahrenheit (40 Celsius) degrees between extreme seasonal highs and lows. Andir has the widest range, 85 Fahrenheit (47 Celsius) degrees. Andir, with an extreme maximum of 115°F (46°C), is not only subjected to blistering heat; it recorded an extreme summer minimum of 30°F (-1°C). This type of climatic disparity is only possible in an extremely arid environment.

Average temperatures range from 46°F (8°C) in the highest heights of the western Tien Shan Mountains, to 91°F (33°C) in the Turpan depression. Average temperature is mainly a function of elevation. Figure 4-30 clearly shows this relationship.

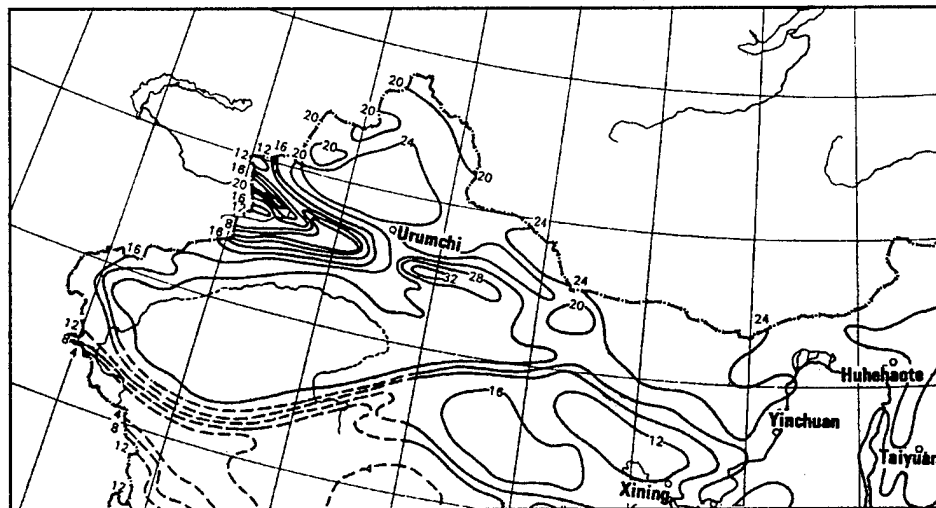


Figure 4-30. Mean July Temperatures (°C). The isopleths on this chart show the correlation between elevation and mean temperature. The dashed lines indicate extrapolated temperature data.

The hottest temperature ever recorded in northwest China, 122°F (49.8°C), was at the airport in the Turpan depression. The city of Bachu nearly eclipsed this record with an extreme maximum of 120°F (49°C). Additionally, the cities of Andir, Dunhuang, Karamay, Korla, and Urumqi have all recorded temperatures in excess of 113°F (45°C). Curiously, the extreme maximum temperature in the Gobi Desert was only 109°F (43°C), recorded at Mandal, at the northeastern fringe of the desert. The highest temperature found in the heart of the Gobi Desert was 108°F (42°C) at Ejin Qi. The lowest extreme maximum found at any major location in northwest China was 93°F (34°C) at both Baytik

Shan and Mazong Shan. Both locations are above the 1,600-meter elevation.

The highest mean daily maximum temperatures are concentrated in the Gobi Desert and Turpan depression. These areas usually see daily high temperatures above 95°F (35°C). The Altai Mountains and the mountains along the southern periphery of the region record the lowest mean daily maximum temperature. These areas record daily high temperatures near 77°F (25°C). Figure 4-31 shows the range of July's mean daily maximum temperatures in northwest China.

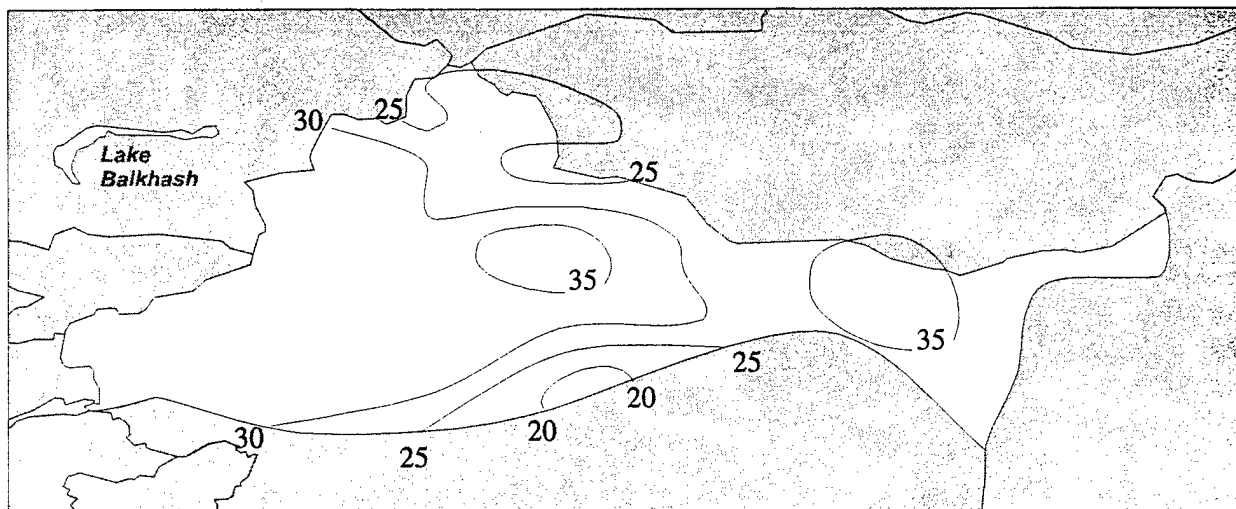


Figure 4-31. July Mean Maximum Temperatures (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

Baytik Shan, with a temperature of 28°F (-2°C), holds the record for extreme summertime minimum temperature found in northwest China. Numerous locations in the region have also recorded temperatures at, or below, freezing, during the summer. As might be expected, the site with the highest extreme minimum temperature on record is Turpan, with a temperature of 52°F (11°C).

Curiously, Figure 4-32, which depicts mean daily minimum temperatures for July, is not a mirror

image of the mean daily maximum temperatures. Some of the lowest mean daily minimum temperatures are recorded in the Dzungarian and Tarim basins. The extreme aridity of the enclosed basins allow for cold air to pool and create a greater range than for other areas at a similar latitude. However, the highest mean daily minimum temperatures are recorded where they are expected—in the Gobi Desert and in the Turpan depression.

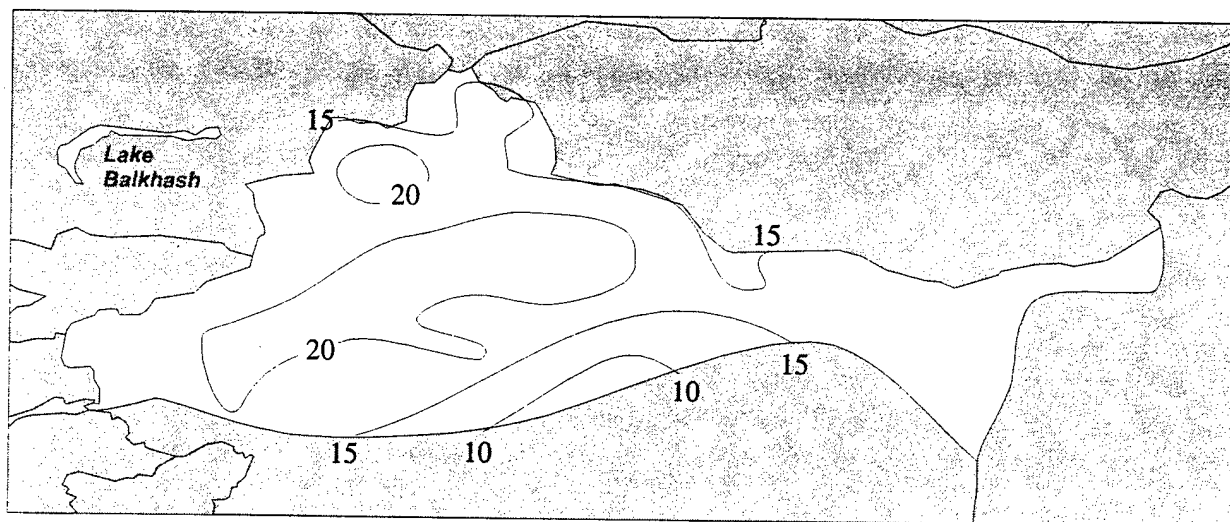


Figure 4-32. July Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

Hazards.

Duststorms/Sandstorms. Duststorms and sandstorms can occur anytime during the year. The two primary factors required for duststorms/sandstorms are strong solar heating and mean wind speeds greater than 15 knots. The arid soil, along with sparse vegetation, make the deserts of Xinjiang, Gansu, and the Gobi prime areas for this phenomenon. During the 30 or more sandstorms that occur in the region each year, both dust and sand are lifted as high as 13,000 feet (4,000 meters) AGL. Visibility is restricted to near zero for usually 2 hours, but conditions can persist for as long as 24 hours.

Blowing dust and sand are the most common and most serious hazards to operations in northwest China. Dust is a finer, smaller atmospheric particle that is nearly always present in the deserts. Sand is a larger, more coarse particle that requires greater wind speeds to be lifted and transported. Additionally, stronger winds and longer trajectories will cause sand and dust particles to be lifted higher. Aircraft downrush raises dust and sand from the

desert floor, reducing visibility in the immediate vicinity of the aircraft. Also, dust and sand enter engine intakes and cause damage. During severe sandstorm conditions, ablation of windscreens and other aircraft parts can occur. Persistent dust conditions also cause problems with dry skin, sore throat, and cracked lips. Dust also contributes to radio signal degradation. A heavy electrostatic discharge may result from the impact of windblown particles striking an object. The surprisingly high-voltage sparking associated with these electrostatic discharges can pose a hazard to personnel and equipment.

Flash Flooding. The sparse vegetation and arid soil of the Takla Makan and Gobi deserts make these regions extremely susceptible to flash floods. Most of the annual precipitation is recorded during brief, heavy summer downpours. The dry riverbeds that cross the deserts briefly fill with rapidly flowing currents. However, even after the most extensive series of storms, the riverbeds dry up. Some of the water evaporates into the atmosphere, but most of it drains into underground aquifers.

Trafficability. Desert areas of China are mostly flat to undulating sandy and gravelly plains. Some are broken by flat-bottomed ravines and rocky crests. The soils are predominantly sandy and vary in thickness from thin to very deep. In many places, shallow soils are covered by a layer of gravel or rock rubble. Some areas have dunes that vary in size and shape and extend up to 30 miles (50 km) in length. Conditions for movement are fair to very good on flat, gravelly plains. In areas with deep, sandy soil, conditions are poor to unsuitable. In dune areas, movement is restricted to inter-dunal routes. Conditions in other areas of the desert are fair except in rough, dissected terrain and in areas of rock outcrops and bouldery surfaces.

Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadow, intensely terraced hills, and permanent snowfields. The soils are predominantly fine grained and consist of clays and silts. The soil type range, however, includes sizable areas of sand and gravel. In the mountains and hills during the wet season, movement is virtually impossible except along established routes and in valley bottoms where coarse-grained soils may exist.

General Weather. Fall, the shortest season of the year is a rapid transition from summer to winter. The Turpan depression has the shortest fall of any location in China; it lasts a mere 33 days. The season is only slightly longer at other locales in northwest China. By mid-September, the Tibetan 200-mb anticyclone is gone and the subtropical jet has moved from the Sino-Mongolian border to a position over north-central Tibet. The polar jet

reappears and strengthens over south-central Mongolia. As the Azores high migrates south, the moisture available to northwest China is greatly diminished. Additionally, the low-level moisture from the Arctic Ocean is also reduced. The decrease in solar radiation causes the arid ground and dry air mass to cool, and by mid-October, the Siberian high starts to form. By the end of the month, the Siberian high is firmly entrenched over western Mongolia. This signals the onset of winter.

Sky Cover. As fall progresses, the atmosphere over northwest China becomes increasingly stable. At the beginning of the season, cumuliform type clouds are still the dominant type. As the Siberian high begins to dominate the region, stratiform-type clouds become the norm in the stable air mass. The occasional frontal passage from the Atlantic, via central Asia, brings mostly mid- and upper-level clouds. The mean total of clouds at all levels across the region is between 30-40 percent (scattered) coverage. Low-level Arctic Ocean moisture funnels through the Irtysh valley into the Dzungarian basin and occasionally forms stratus and nimbostratus.

Several stations in the Dzungarian basin and along the northern edge of the Tien Shan Mountains report

ceilings below 3,000 feet up to 5 percent of the time. As the flooding in the Huang River delta begins to subside, the low-level moisture source slowly begins to disappear. Haliut, Mandal, and Hails report ceilings below 3,000 feet up to 10 percent of the time in September. The progressive loss of the moisture source is reflected by these stations that report low ceilings only 5 percent of the time in October. Ceilings below 3,000 feet are reported in the Tarim basin and the Gobi Desert less than 1 or 2 percent of the time. It is not uncommon for several years to pass between reports of low ceilings at many sites in these areas. Figure 4-33 shows the scarcity of low ceilings at selected locations across northwest China.

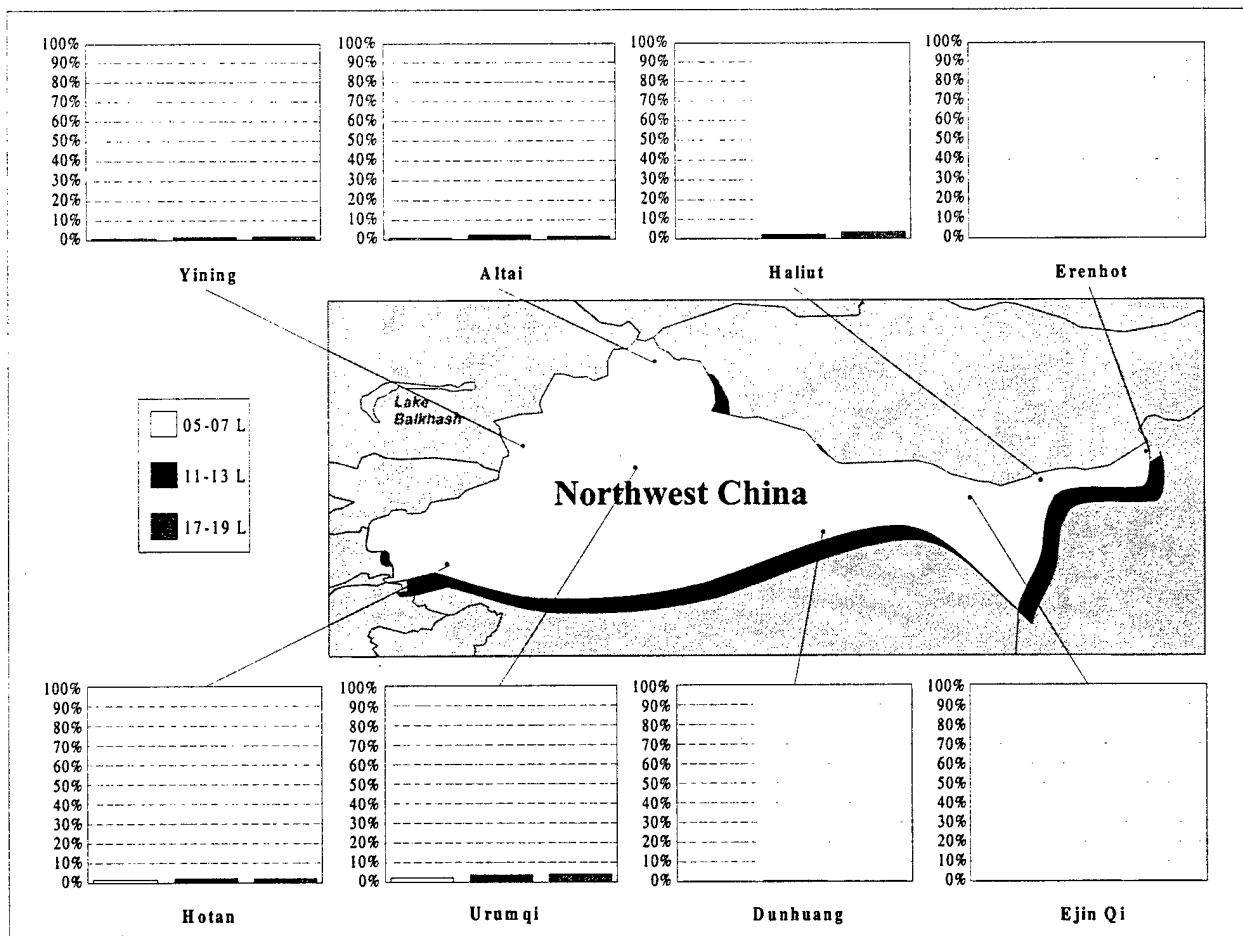


Figure 4-33. October Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Fall in northwest China is a season of excellent visibility. The air is clean and crisp. Figure 4-34 shows that most sites report visibility below 4,800 meters less than 2 percent of the time. Stations along the southern rim of the Takla Makan Desert report reduced visibility more than 10 percent of the time. These stations record up to 22 days of blowing sand/dust per month. At some hours, Minfeng averages visibility in this reduced category up to 50 percent of the time. The blowing dust/sand is lifted as high as 13,000 feet (4,000 meters); it not only restricts surface visibility, it also impairs flight-level visibility.

Fog causes restrictions to visibility less often. Many locations record no days with fog during this season. Years may pass between occurrences of fog, especially in the Takla Makan and Gobi deserts. Only one station, Baytik Shan, averages more than

1 day of fog a month in the fall. This site, at an elevation of 5,416 feet (1,651 meters) on the northwestern tip of the Baytik Mountains, records 7 days of fog. Baytik Shan is especially susceptible to upslope conditions that produce fog. Nevertheless, visibility below 4,800 meters occurs less than 5 percent of the time.

By late October, the Siberian high is over western Mongolia. Subsidence associated with this feature produces conditions favorable for stagnant air. Visibility is restricted by trapped haze and smoke in valleys and near riverbeds. Visibility is typically at its worst during the hours near dawn. By late morning, surface heating breaks the radiation inversion created during the night, and the visibility improves. The cycle repeats itself after dark as air is again trapped under the redeveloping inversion.

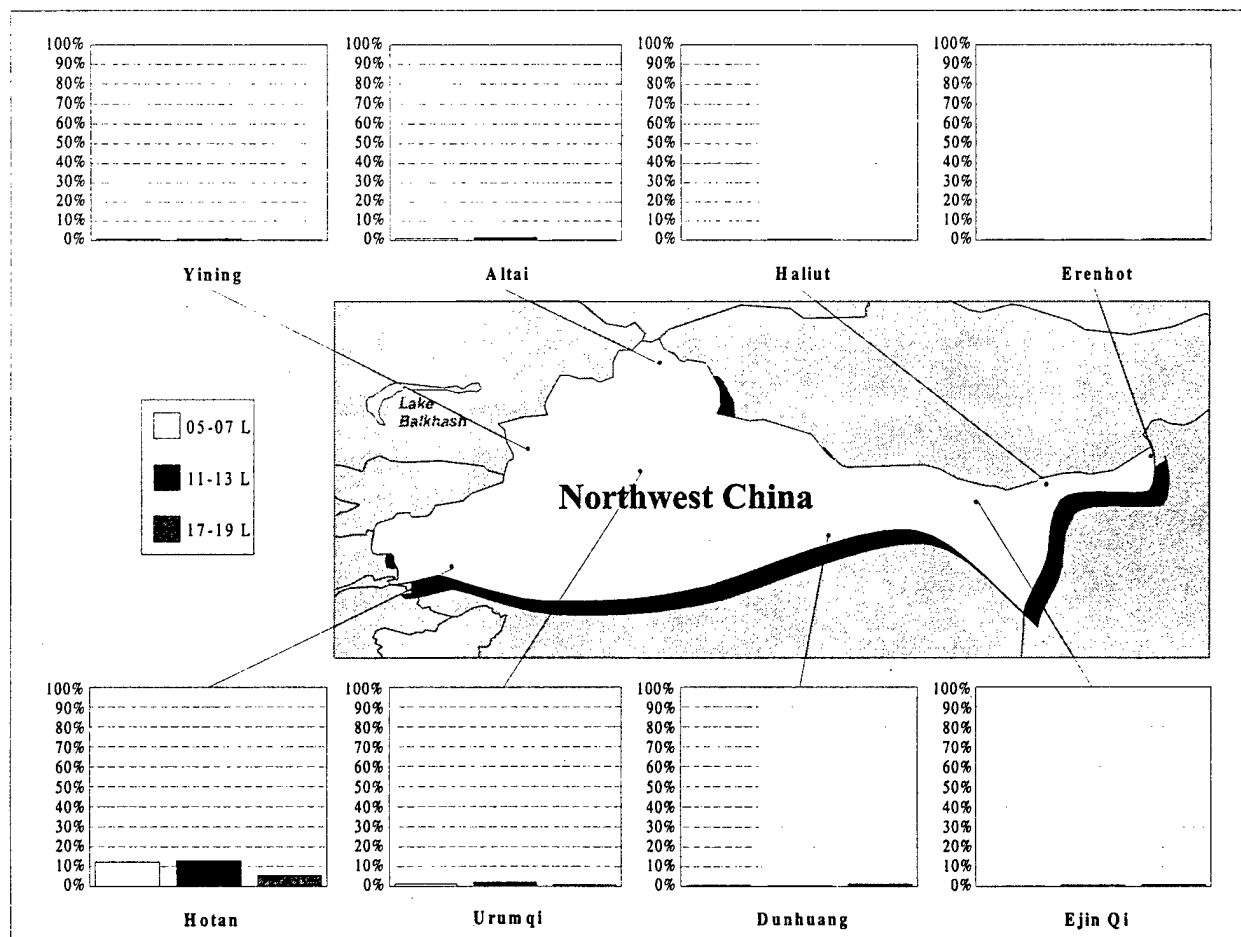


Figure 4-34. October Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. In this transition season, localized mountain/valley breezes are more pronounced. Terrain also plays an important role in defining wind speed and direction. As the season progresses, the subtropical jet migrates from a position over central Tibet to its wintertime position south of the Himalayas. The polar jet strengthens and moves from central Mongolia to a position over the Sino-Mongolian border. As the Siberian high becomes more dominant in late fall, outbreaks of cold air cause the polar jet to dip into northwest China. After

the associated front passes, the Siberian high moves back in to dominate the region.

The full influence of the Siberian high is best displayed by the difference in the 06Z wind roses (see Figure 4-35), for September and October, at Haliut. Notice the high frequency of southerly drainage winds, present during every month, is still evident. The frequency and intensity of the northwesterly winds shows a significant increase in October (see Figures 4-36 and 4-37).

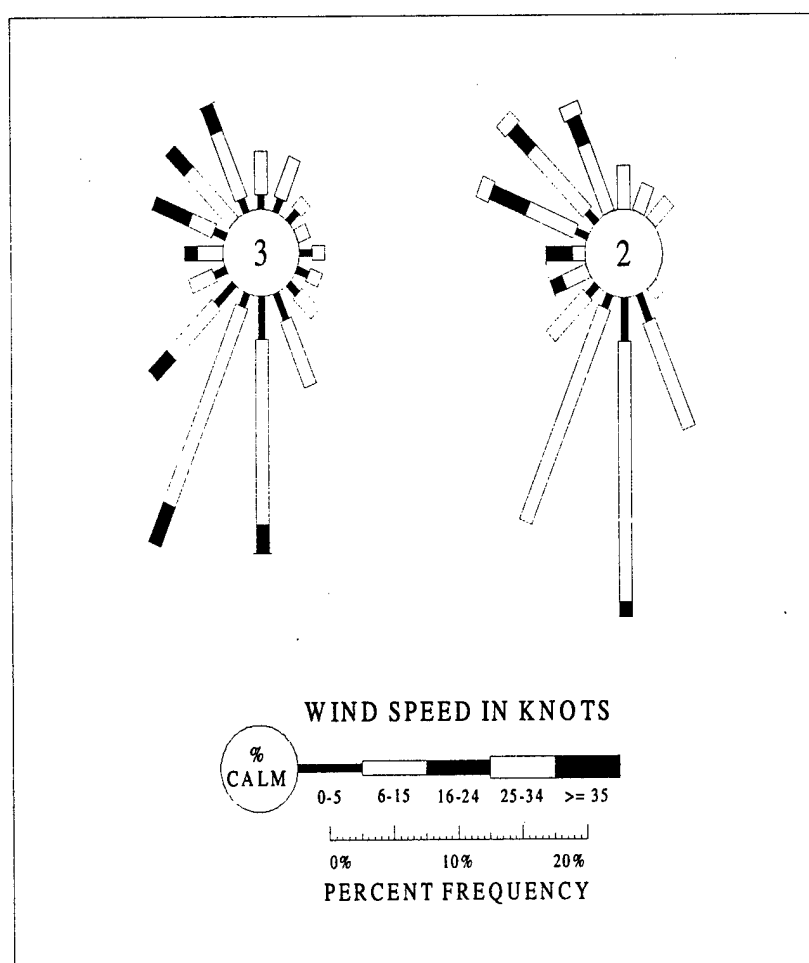


Figure 4-35. September and October 06Z Surface Wind Roses (Haliut). The contrasting influences of late summer and early winter are easily seen at Haliut.

The highest wind speed for the season was 60 knots, recorded at Hoboksar and Minfeng. Just south of Hoboksar, Karamay recorded an extreme maximum wind speed of 58 knots. Erenhot, in the northeastern Gobi Desert, also recorded a maximum wind speed

of 58 knots. For many locations in the region, the extreme recorded wind speeds for fall are the lowest for all the seasons. For example, the wind speed at Dunhuang has never exceeded 27 knots in the fall. In every other season, Dunhuang has recorded extreme wind speeds of up to 49 knots.

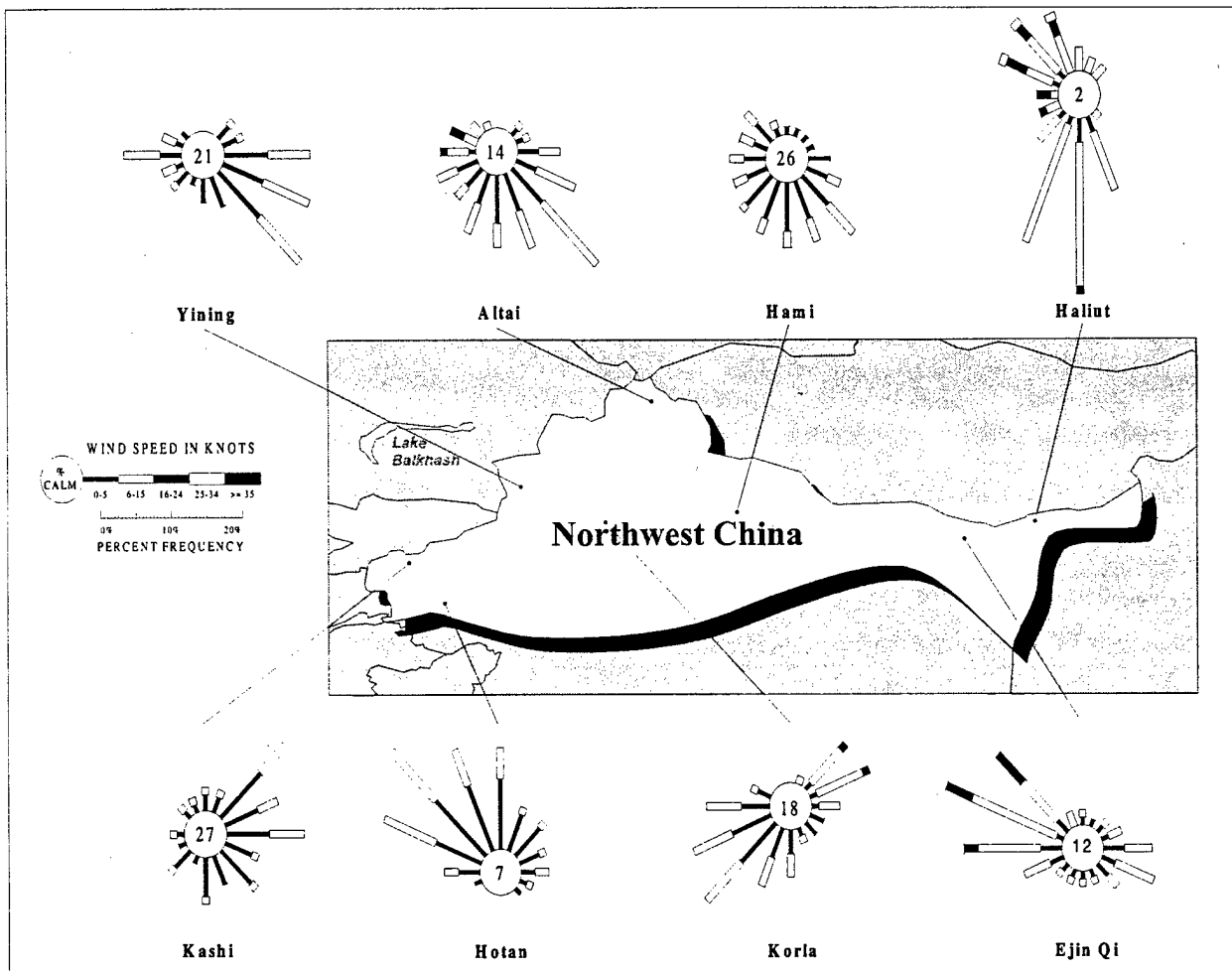


Figure 4-36. October 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on frequency and location for various locations within northwest China.

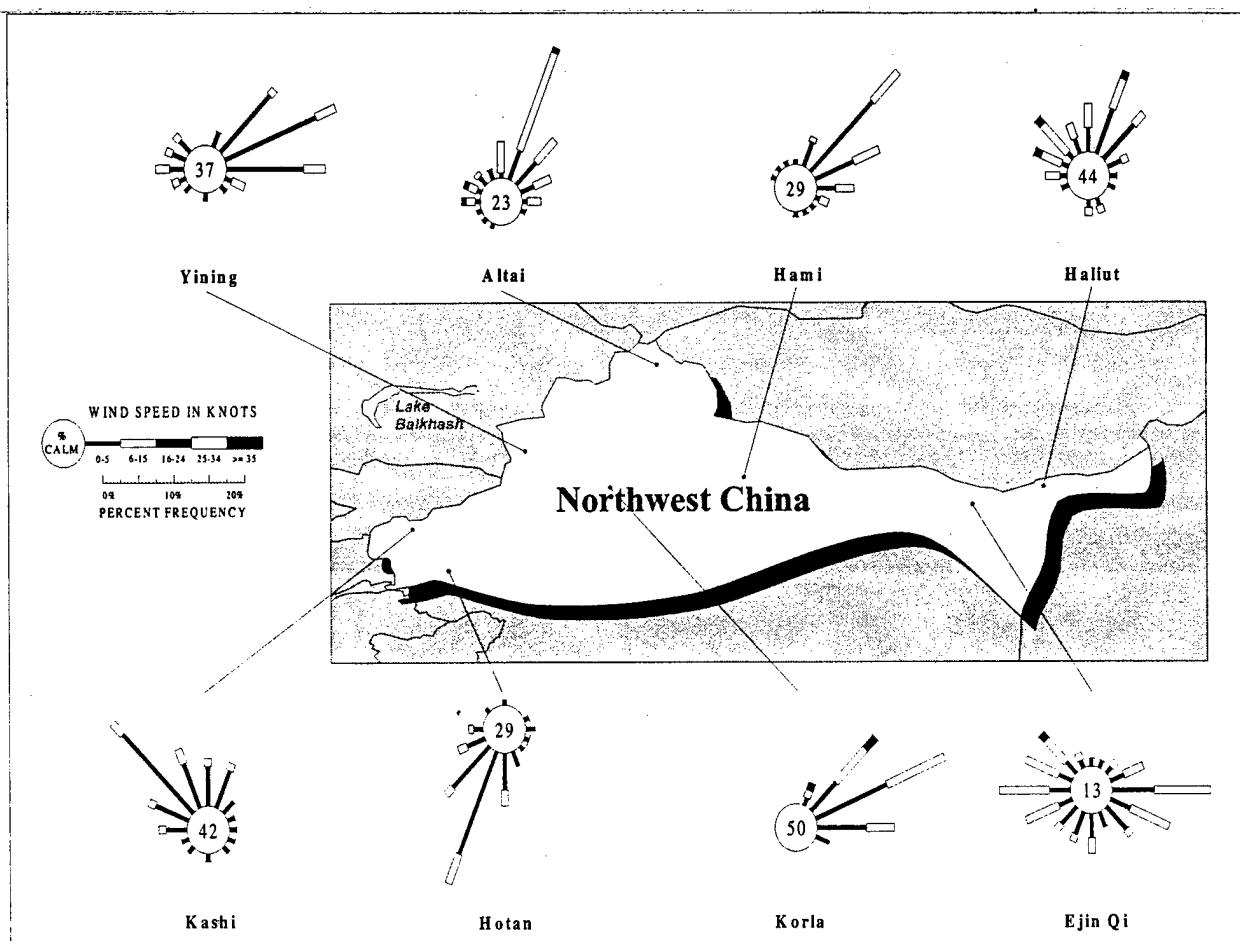


Figure 4-37. October 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on frequency and location for various locations within northwest China.

Winds Aloft. During fall, the subtropical jet is situated over central Tibet, and the main branch of the polar jet extends from central Mongolia to northeastern China. The predominate wind direction from 700 mb up to 300 mb is westerly, with only minor variance between northwesterly and southwesterly (see Figure 4-38). Both the subtropical jet and the polar jet are best depicted at the 200-mb level. Mean wind speeds range from

approximately 40 knots over western Xinjiang Province to near 60 knots over the northeastern Gobi Desert. Even in the areas with the highest winds, the jet stream exceeds 90 knots less than 5 percent of the time. The wind roses from the eastern section of the region depict the greatest frequency of higher wind speeds. These same stations best indicate the influence of the Siberian high at the 850-mb level. During late fall polar outbreaks, the polar jet dips southward towards the Gobi Desert.

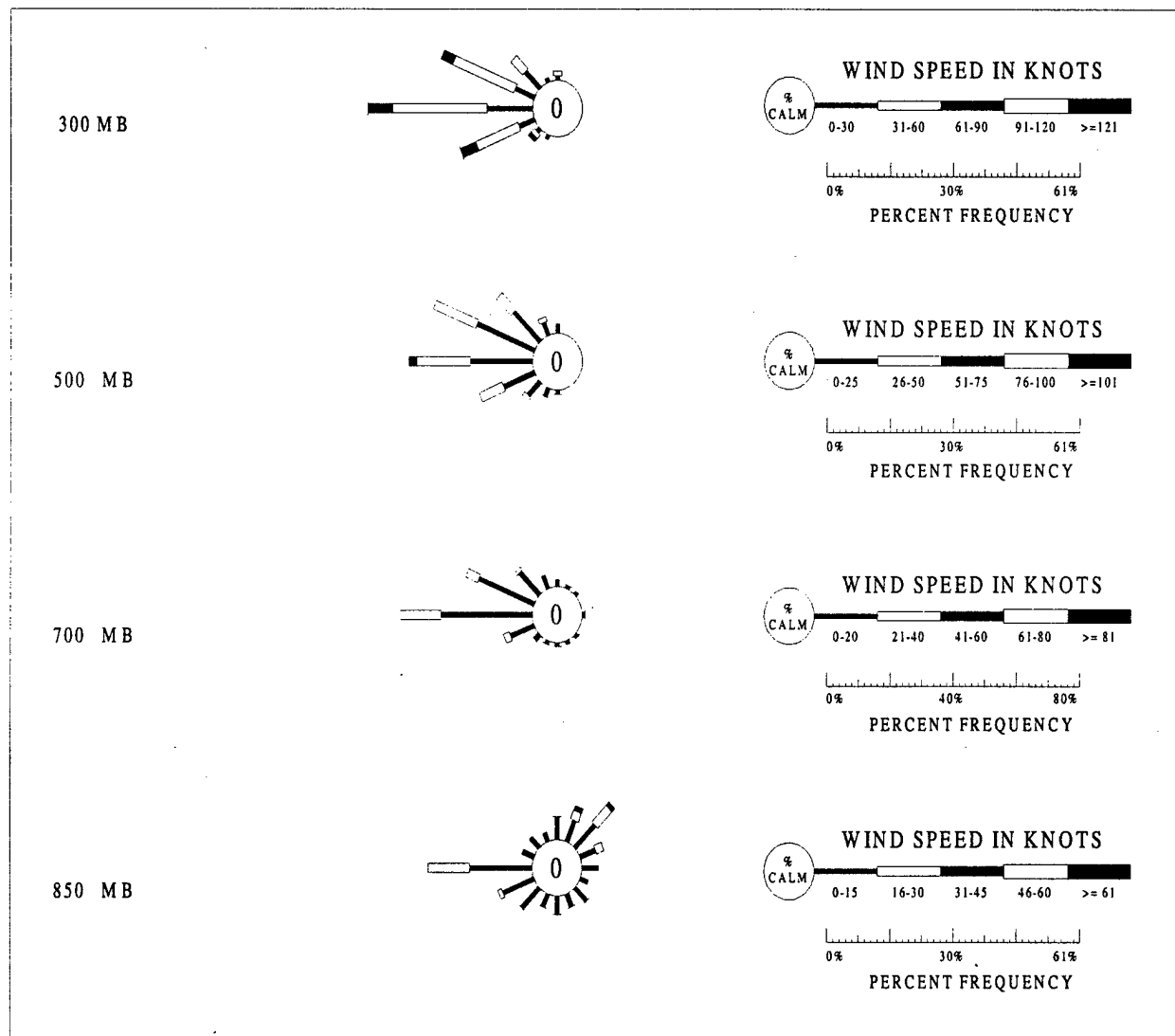


Figure 4-38. October Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Altai. Note: Each wind rose has a tailored legend.

Fall

Precipitation. Fall marks a sharp drop in monthly mean precipitation totals across the entire region. The comparatively high precipitation amounts found in summer quickly drop during the transition to an arid winter season. The cumuliiform clouds found in the early weeks of September, a holdover from summer, produce brief showers with little rainfall. The loss of low-level moisture across the region has a notable effect on cloud formation, especially in the Tarim basin and the Gobi Desert. With no moisture available, the scattered afternoon cumulus is not able to form. This results in a sharp drop in precipitation totals; less than 5 mm of rain occurs at sites in the Tarim basin and Gobi Desert.

Low-level moisture from the Arctic Ocean that still flows through the Irtysh valley into the Dzungarian basin and the mountains of northern Xinjiang is more conducive to cloud formation than in the southern and eastern deserts. In the stable air mass, the cumulus and cumulonimbus clouds are replaced by stratocumulus, stratus, and nimbostratus clouds. The summer rainshowers are replaced by steady rain and drizzle. The brief, heavy downpours found in summer are replaced by extended periods of steady, but light rain. Summertime mean precipitation totals in the Tien Shan and Altai mountains of more than 100 mm per month decrease to approximately 10-25 mm of precipitation. Only isolated spots in the Tien Shan record totals of approximately 50 mm. The Dzungarian basin as a whole shows a sharp decline in precipitation totals from September to October. The 25-50 mm recorded in the basin in September drops to only 5-10 mm in October. A wide expanse of the western Dzungarian basin, along the lee side of the northern Tien Shan Mountains, averages less than 5 mm of precipitation

in October. More than 50 mm of precipitation is recorded on the windward side of the mountains. Figure 4-39 shows this contrast.

With the exception of the stations in northern Xinjiang, the rest of the region experiences a decrease in the number of rainfall days. Yining, on the windward side of the northern Tien Shan, actually has a slight increase in the number of rainfall days—8 days in September to 9 days in October. This indicates the dominant northwesterly flow and the increasing importance of Arctic Ocean moisture to the region. Most stations in northern Xinjiang average 7 rain days per month in fall. Sites located along the windward side (northern face) of the Qilian Mountains experience a similar sharp drop in the number of rain days during fall. The majority of the 10 days at Zhangye, and the 9 days at Minqin occur during early September. By October, this high number of rain days drops to 6 at Minqin and 4 at Zhangye. The overall drop in number of rain days is partly replaced by a slight increase in the number of days with snow.

A considerable part of the western Tien Shan Mountains is glacier-covered year round. The highest elevations of this range are under permanent snow cover. The first snowfall of the season usually occurs by mid-September above the 4,000 meter height. The stations located in the mountainous sections of northern Xinjiang average 1 or 2 snowfall days in September. This total increases to 3 or 4 days in October, with the exception of Baytik Shan, which records 8 snowfall days. The stations in the northeastern Gobi Desert usually record their first snow in October; normally, 2 or 3 snow days are recorded in October. The Tarim basin and Takla Makan Desert normally record no snow days in fall.

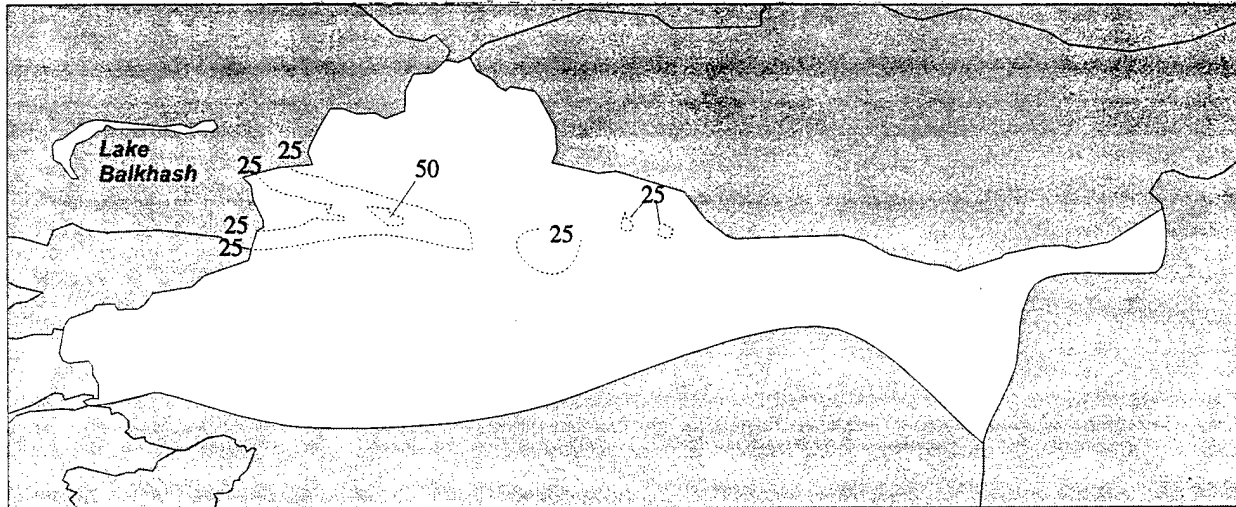


Figure 4-39. October Mean Precipitation (mm). The isopleths show the contrast between the amounts of precipitation recorded in the mountains and the deserts.

Temperatures. Fall in northwest China is a season of rapid and sharply defined transition from the burning heat of summer to the bitter cold of winter. After the autumnal equinox, the amount of available sunshine decreases. As the vast central Asian landmass cools, the shallow, cold, barotropic Siberian high forms in the Lake Baikal area. The first outbreaks of arctic air from northern Siberia reinforce the central pressure of the Siberian high. By mid-October, the Siberian high is firmly entrenched and sends pulses of extremely cold air across China.

By early October, daily mean temperatures drop below freezing in the western and central sections of the Tien Shan Mountains (see Figure 4-40). Mean daily temperatures rise with descending heights. A large section of the Altai Mountains, the easternmost Tien Shan Mountains, and the northern Gobi Desert all record mean daily temperatures in the 39° to 46°F (4° to 8°C) range. Mean temperatures in the 46° to 54°F (8° to 12°C) range are found in the Dzungarian basin, northern Gansu Province, and the southern Gobi Desert. Stations in the eastern Tarim basin, along the southern edge of the Takla Makan Desert, also have mean temperatures that range from 46° to 54°F (8° to 12°C). Mean temperatures exceed 54°F (12°C) in only a few locations along the northern and western rims of the Tarim basin and in the Turpan depression. With a daily mean temperature of 57°F (14°C), Turpan has the highest daily mean temperature.

Diurnal variation is a good indicator of moisture content in the atmosphere (i.e., low relative humidity equates to a high diurnal variation and vice versa). Sites with the highest moisture content (mountain stations) have the smallest diurnal variation. Karamay, in the northern Tien Shan Mountains, has an average diurnal variation of only 14 Fahrenheit (8 Celsius) degrees. Several stations in the Tien Shan or Altai mountains have mean diurnal variations of less than 22 Fahrenheit (12 Celsius) degrees. On the other hand, Andir, on the southern edge of the Takla Makan Desert, has a mean diurnal

variation of 34 Fahrenheit (19 Celsius) degrees. Just to the west, Minfeng has a diurnal variation of 32 Fahrenheit (18 Celsius) degrees. A line of stations along the southern edge of the Takla Makan from Minfeng to Dunhuang has mean diurnal variations of at least 29 Fahrenheit (16 Celsius) degrees. Stations in the western and central Gobi Desert have a mean diurnal variation of between 23 and 27 Fahrenheit (13 and 15 Celsius) degrees. The stations in the eastern Gobi, just to the north of the Yin Mountains, have a slightly lower variation. Mandal, Hails, and Haliut have mean diurnal variations of only 20 Fahrenheit (11 Celsius) degrees. The advection of moisture from the Huang River delta causes these stations to have a smaller variation than that of surrounding stations.

Values for mean daily maximum range from 45°F (7°C) at Baytik Shan to 70°F (21°C) at Turpan (see Figure 4-41). As outbreaks of Siberian air filters through the Irtysh valley, a pool of cold air forms in the Dzungarian basin. As a result, stations in this area record mean daily maximums below 54°F (12°C). These temperatures are significantly lower than those found in the Tarim basin, on the southern side of the Tien Shan Mountains. Numerous stations in the Tarim basin have mean daily maximums of 68°F (20°C), and every station in the basin records an average daily maximum of at least 64°F (18°C). Maximum temperatures in the Gobi Desert are slightly more moderate. Stations in the Gobi record mean daily maximums of between 57°F (14°C) and 61°F (16°C). The higher relative humidity in the vicinity of Hails, Haliut, and Mandal also moderates their mean maximums. However, since this advection mechanism is only active during the afternoon hours, only the maximum temperatures (not the minimum temperatures) are moderated. These locations have mean high temperatures of only 52°F (11°C).

With the exception of only a few stations, minimum temperatures are usually at or above freezing (see Figure 4-42). Morning lows in the Dzungarian basin range from 28° to 43°F (-2° to 6°C). The dry air of

the Tarim basin allows the low temperatures to drop to much lower values than would be expected. In particular, the three stations on the southern edge of the Takla Makan Desert—Minfeng, Qiemo, and Andir—have mean minimum temperatures of between 34° and 36°F (1° and 2°C). In contrast, other stations on the western and northern sides of the Tarim basin have mean low temperatures between 39° and 45°F (4° and 7°C). Mean low temperatures in the Gobi Desert range from 27° and 34°F (-3° to 1°C). The 46°F (8°C) mean low temperature at Turpan is the highest mean low temperature in northwest China.

The most extreme maximum October temperature in northwest China was 99°F (37°C), recorded at Qiemo and Andir. Mazong Shan holds the record for the lowest extreme maximum temperature of

any location in northwest China, 75°F (24°C). Dunhuang and Ejina, with a temperature of 84°F (29°C), share the record for the extreme high temperature in the Gobi Desert.

The October record low for northwest China was -22°F (-19°C), recorded at Mazong Shan. Most of the stations in the Dzungarian basin have recorded extreme minimum temperatures of between 5° and 0°F (-15° and -18°C). Extreme lows found in the Tarim basin are only slightly more moderate. The 12°F (-11°C) recorded at Andir and Qiemo holds the record for the Tarim basin. The drier air found in the Takla Makan allows for a greater range in extremes. Elsewhere in the Tarim basin, extreme lows range from 28° to 19°F (-2° to -7°C). Extreme lows in northern Gansu Province and the Gobi Desert range from 10° to 3°F (-12° to -16°C).

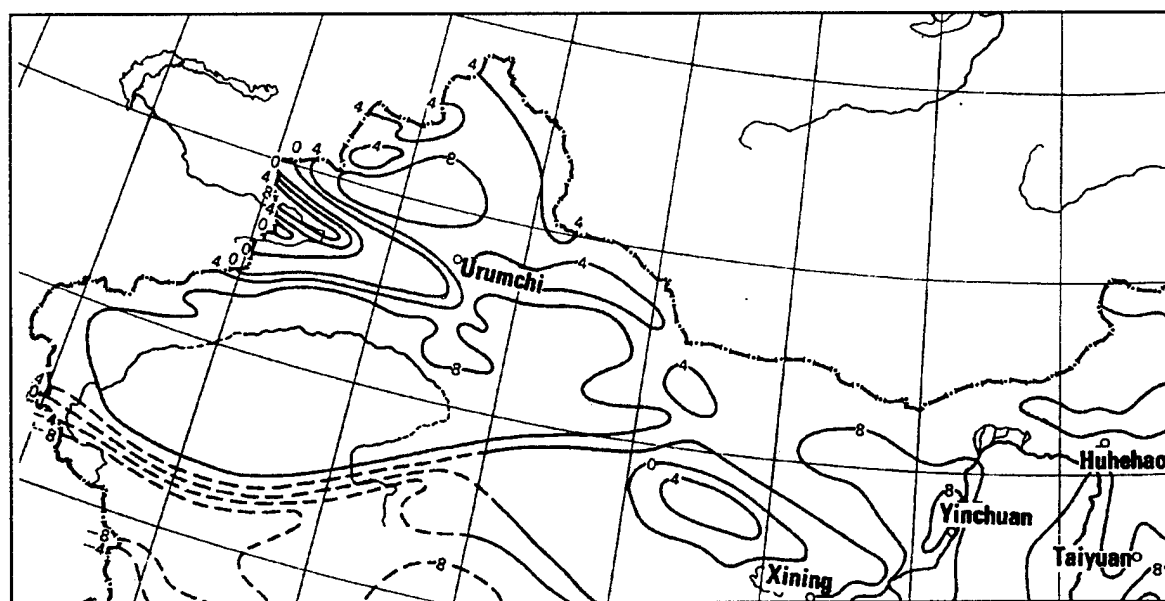


Figure 4-40. Mean October Temperatures (°C). The isopleths on this chart show the correlation between elevation and mean temperature. The dashed lines indicate extrapolated temperature data.

A large, warm pool of 68°F (20°C) air that extends across the Tarim basin and the Turpan depression highlights the mean daily maximums as depicted in Figure 4-41. The coldest mean daily maximums are restricted to the Altai and Kunlun Shan mountains. The mean daily maximums in the mountains rarely exceed 50°F (10°C). The mean daily maximum temperatures across the eastern half of northwest China are mostly isothermal, near 59°F (15°C).

Very little contrast in mean daily minimums is found across northwest China (Figure 4-42). Most of the region records daily low temperatures at, or near the freezing point. A very small section of the Kunlun Shan Mountains records the coldest mean daily minimums, an average near 23°F (-5°C). The warmest mean daily minimums are found across the Takla Makan Desert and the Turpan depression. These areas record mean daily minimums just above 41°F (5°C).

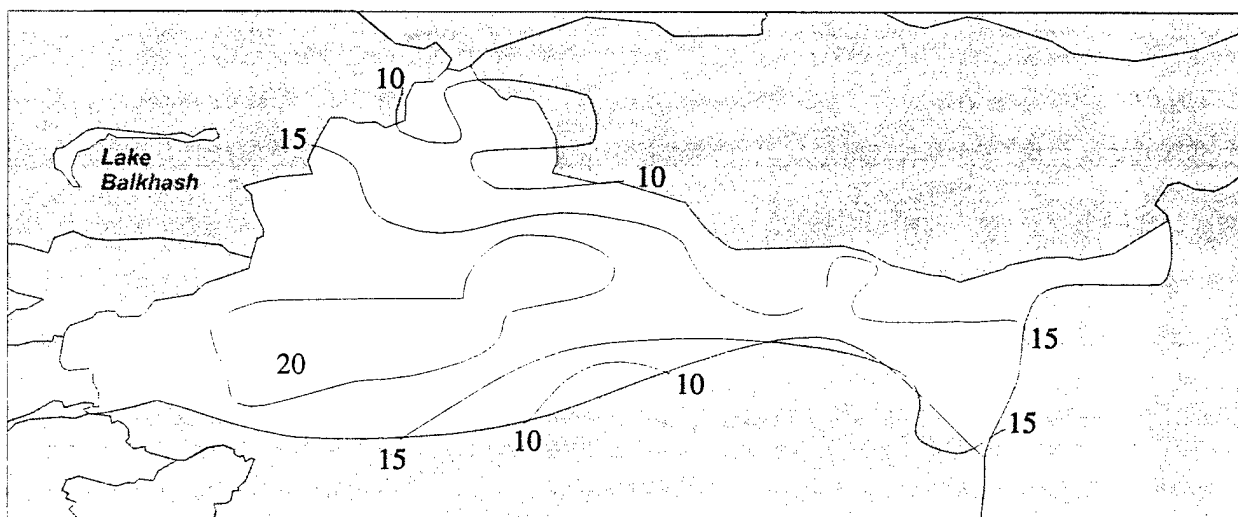


Figure 4-41. October Mean Maximum Temperatures (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

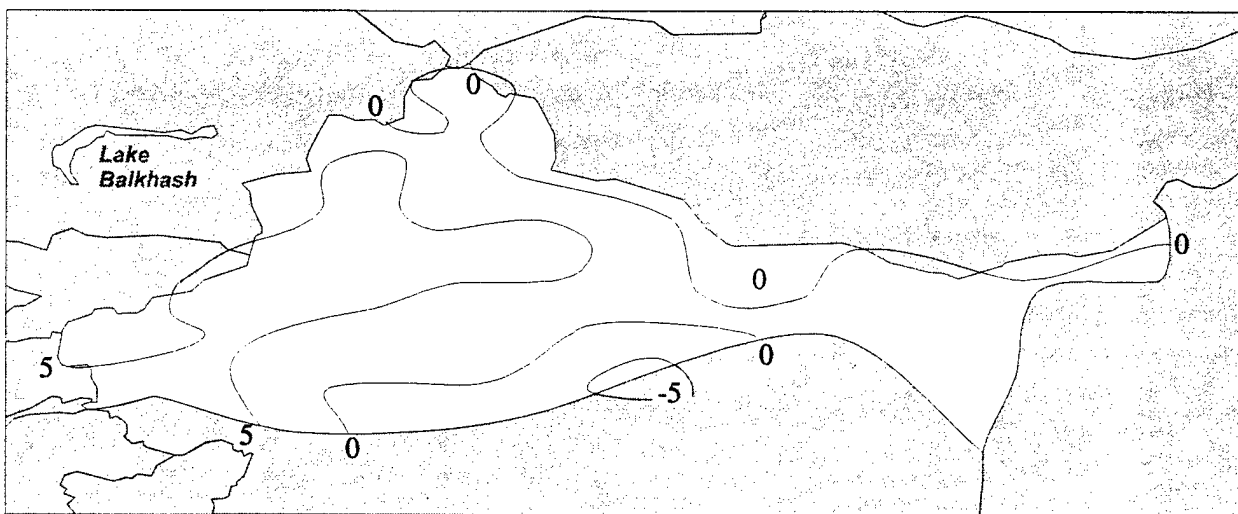


Figure 4-42. October Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

Hazards.

Aircraft Icing. Icing is mainly restricted to altocumulus and altostratus found in the migratory frontal systems that pass through the region from the distant Atlantic Ocean moisture source. Low-level moisture is normally too scarce to allow any more than a trace of icing. Light-to-moderate rime icing is found in the light but nearly continuous snowfall found over the Tien Shan and Altai mountains.

Turbulence. Strong post-frontal northerly winds, blowing perpendicular to the east-west oriented Tien Shan Mountains, produce conditions conducive to mountain-wave turbulence. With sufficient moisture available, altocumulus standing lenticular (ACSL) clouds will form on the lee side of the ridge line. Since the air is usually too dry, ACSL will not normally be visible, but moderate-to-severe turbulence will still exist up to 45-60 miles (75-100 km) downstream and to an altitude of 45,000 to 95,000 feet (15 to 30 km).

The mountain wave usually breaks down on the second day after the frontal passage. The winds shift from a northerly direction to an easterly or southeasterly direction. Once the perpendicular component decreases, the mountain wave and the resulting turbulence dissipates. The peak time for mountain wave occurrence is from late winter into spring. This ties in with the weakening of the Siberian high and the opening of the storm track into northwest China.

Duststorms/Sandstorms. Duststorms and sandstorms can occur anytime during the year. The two primary factors required for duststorms/sandstorms are strong solar heating and mean wind speeds greater than 15 knots. The arid soil, along with sparse vegetation, make the deserts of Xinjiang, Gansu, and the Gobi prime areas for this phenomenon. During the 30 or more sandstorms that occur in the region each year, both dust and sand are lifted as high as 13,000 feet (4,000 meters) AGL. Visibility is restricted to near zero for usually 2 hours, but conditions can persist for as long as 24 hours.

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Trafficability. Desert areas of China are mostly flat to undulating sandy and gravelly plains. Some are broken by flat-bottomed ravines and rocky crests. The soils are predominantly sandy and vary in thickness from thin to very deep. In many places, shallow soils are covered by a layer of gravel or rock rubble. Some areas have dunes that vary in size and shape and extend up to 30 miles (50 km) in length. Conditions for movement are fair to very good on flat, gravelly plains. In areas with deep, sandy soil conditions are poor to unsuitable. In dune areas, movement is restricted to inter-dunal routes. Conditions in other areas of the desert are fair except in rough, dissected terrain and in areas of rock outcrops and bouldery surfaces.

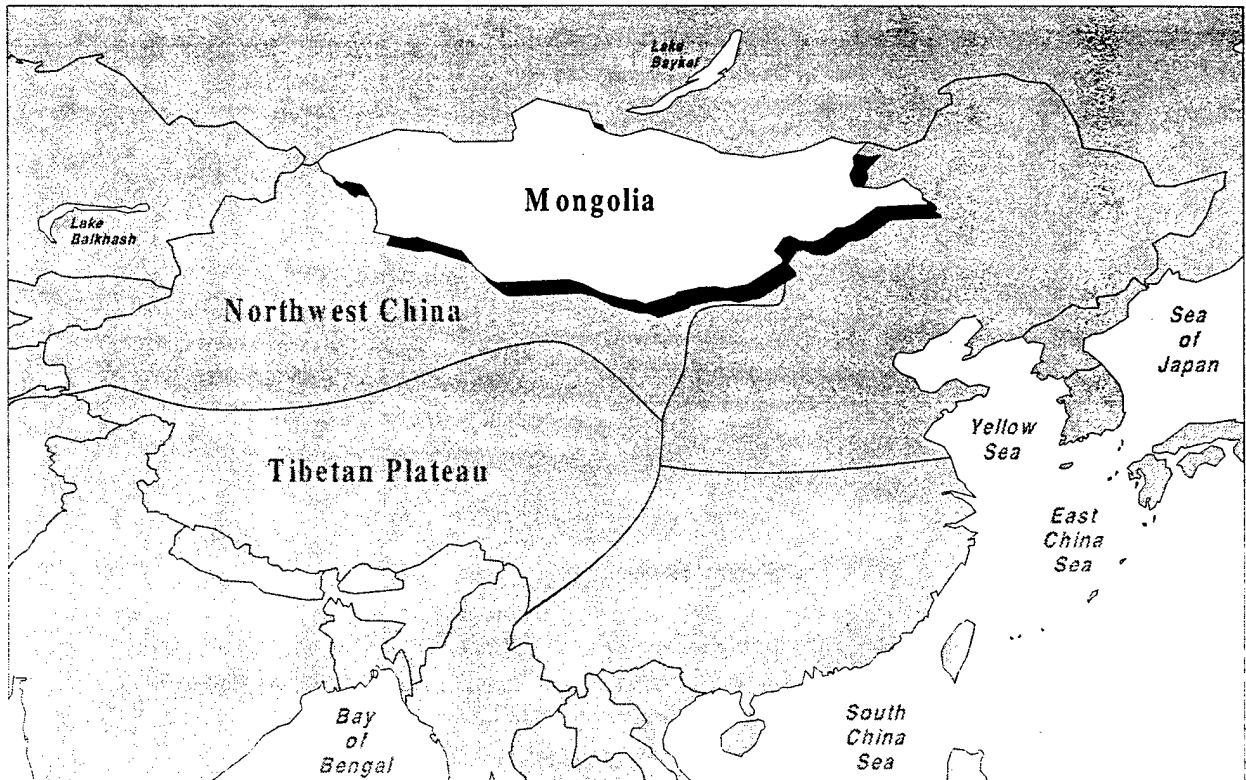
Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadow, intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine grained, and consist of clays and silts. The soil type range, however, includes sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and intensive, man-made terracing. Conditions are fair to good in some alpine meadows especially if frozen, and conditions are also fair to good in some valley bottoms.

Chapter 5

MONGOLIA

This chapter describes geography, major climatic controls, special climatic features, and general weather (by season) for the climatic zone that makes up Mongolia.



Geography of Mongolia	5-2
Major Climatic Controls of Mongolia	5-6
Special Climatic Features of Mongolia	5-7
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Spring (April-May)	5-21
Summer (June-August)	5-32
Fall (September-October)	5-44

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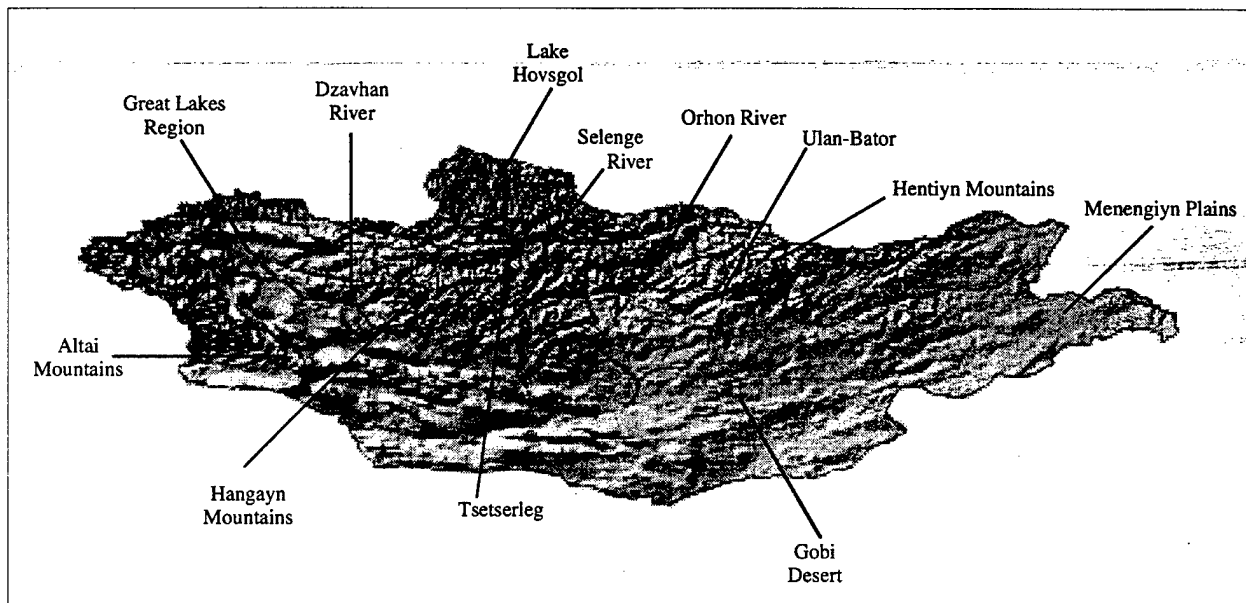


Figure 5-1. Topography. This map shows major Mongolian terrain features.

Boundaries. Mongolia is a landlocked nation, located in north-central Asia between Russia and China. Mongolia is slightly larger than the state of Alaska. Of the 5,000 miles (8,100 km) that make up the total land boundary, nearly 60 percent is shared with China. The remainder is shared with Russia. Mongolia is located more than 400 miles (650 km) away from the closest bodies of water, the Korea Bay and the Bay of Chihli. The Sea of Japan is more than 560 miles (900 km) away from the easternmost tip of Mongolia.

Seasons. There are two main seasons in Mongolia, a long winter and a shorter summer. These two seasons are separated by two transitions, a short spring and an even shorter fall.

Mountains. Mongolia has three primary mountain ranges and several other minor ranges. The primary mountain ranges of Mongolia are located in either the western or northern sections of the country. The mountains in western Mongolia are an extension of the mountains found in northwestern China, and the mountains of northern Mongolia are a continuation of the ranges of southern Siberia. Most of the mountain ranges of Mongolia are situated in either an east-west or northwest-southeast orientation.

This tends to reinforce and funnel the predominant northwesterly winds into the southern and eastern desert plateaus.

The three primary mountain ranges of Mongolia are the Altai and Hangayn mountains in western Mongolia, and the Hovsgol Mountains in northern Mongolia. The Altai Mountains extend from the western border with China to the southeast for more than 1,000 miles (1,600 km). The highest peak in the range, Mt. Nayramdal, is located at the extreme western tip of Mongolia and rises to a height of 14,290 feet (4,355 meters). Numerous other peaks in the range also rise above 13,000 feet (4,000 meters). Much of the Altai Mountains are glacier-covered, and the highest peaks are also permanently covered by snow. The Altai Mountains are paralleled on the north by the Hangayn Mountains. The highest peak in the Hangayn Mountains, Mt. Otgon Tengor, is 12,810 feet (3,904 meters) in height. This peak is located just southeast of the city of Uliastai. Several other peaks in the Hangayn Mountains are higher than 9,800 feet (3,000 meters). The Hangayn Mountains are characterized by gently rising slopes and peaks, usually covered by fine pastures. The Hovsgol Mountains are a southern extension of the Sayan Mountains of Siberia. The highest peak in

MONGOLIA GEOGRAPHY

the Hövsgöl Mountains, Hordil Saridag, is 10,910 feet (3,325 meters) in height and is located just north of Lake Hövsgöl.

The five minor mountain ranges of Mongolia are the Govi Altain, the Hentiyn, the Bulayn, the Büteeliyn, and the Bürengiyn mountains. These ranges average between 4,900 and 8,200 feet (1,500 and 2,500 meters) in height. The Govi Altain Mountains extend for nearly 300 miles (500 km) from the southeastern Altai Mountains and gradually decline into the Gobi Desert. The Hentiyn Mountains extend northeastward for nearly 185 miles (300 km) from the capital of Ulan-Bator before reaching the Russian border. The Bulayn Mountains are a minor range found between the Hangayn and Hövsgöl ranges. The Bulayn Mountains extend for more than 185 miles (300 km) in an east-west orientation. The Büteeliyn and Bürengiyn mountains run parallel to each other, in the north-central section of the country, near the Russian border.

Plains. Much of the north and west of Mongolia, between the primary mountain ranges, is made up of a complex series of basins. The area between the Altai and Hangayn mountains, and the Russian border, is known as the Great Lakes region. This vast basin contains nearly 300 lakes and takes up much of the northwestern corner of Mongolia. The elevation of this basin is between 3,300 and 6,600 feet (1,000 and 2,000 meters). This region is also where the extensive Hovdo River system can be found.

Between the eastern slopes of the Hangayn and the Hentiyn mountains is another extensive basin, the North-Central Mongolian Basin. The southern portion of this basin is one of the main agricultural regions of Mongolia and is where the Orhon and Tuul river valleys are found. Ruins of many ancient communities are also found in this historically important and fertile region.

The Khorgo Basin, located on the northern fringes of the Hangayn Mountains, is home to as many as a

dozen extinct volcanoes and numerous small volcanic lakes. A number of jagged gorges have been cut in the area by several turbulent and swift rivers. In the extreme northern part of the country, near the Russian border, the area surrounding the vast Lake Hövsgöl is another primary basin of Mongolia. The Lake Hövsgöl basin is where several hundred smaller lakes and subterranean caves are found. At the southern tip of the Hangayn Mountains is a basin where the source region of the Orhon River is found. This volcanic region is home to several lakes, volcanic vents, and hot springs. The source stream of this mighty river emits a constant low-pitched roar and is almost invisible in its deep gorge.

Plateaus. The southern and eastern sections of Mongolia are made up of a series of plateaus. The northern edge of the Eastern Mongolian Plateau is framed by the southern rim of the Hentiyn Mountains and extends as far west as the eastern limits of the Hangayn Mountains. This great expanse, which takes up the eastern one-third of the nation, consists of rolling steppe plains and several smaller, flat plains in the extreme east. These flat plains, known as the Menengiyn Plains, have an average elevation between 2,000 and 2,300 feet (600 and 700 meters). The Dariganga area of eastern Mongolia has more than 220 small, stubby massifs containing the cones of extinct volcanoes.

The main Gobi plateau extends along most of the southern portions of the country and is characterized by a series of rolling, oasis-dotted plains. The plateau is mainly rocky, devoid of vegetation, and forms the great Gobi Desert. This vast plateau, which takes up one-third of the area of the nation, begins along the southern periphery of the Altai Mountains in the west. From there it extends between the Chinese border and the Altai and the Govi Altain mountains. The Gobi plateau finally ends in the southeastern section of Mongolia, in the vicinity of Dorono Gobi Province. The northern fringes of the Gobi plateau gradually blend into the southwestern portions of the eastern Mongolia plateau.

MONGOLIA GEOGRAPHY

Lakes, Rivers, and Drainage.

Rivers. The rivers of Mongolia are mainly found in the northern half of the country. The rivers of northwest and north-central Mongolia eventually drain into the Arctic Ocean, and the rivers of eastern Mongolia empty into the Sea of Okhotsk.

The largest river system found in Mongolia is the Selenge River. The Selenge flows through the north-central Mongolian basin before exiting Mongolia and emptying into the Arctic Ocean, by way of Lake Baikal and the Lena River of eastern Siberia. The Egiyn River, flowing from the Hövsgöl Mountains; the Hanuy River, flowing from the southern Hangayn Mountains; and the Ideriyn River, flowing from the north-central Hangayn Mountains, merge near Selenge, before forming the Selenge River.

The primary tributary of the Selenge is the Orhon River, a major river system in its own right. The headwaters of the Orhon are found in the southern Hangayn Mountains, just south of the city of Tsetserleg. The Orhon River flows northeastward before being joined by the Tuul, Harea, and the Yöröö rivers. The Tuul River originates in the northwestern Hentiyn Mountains, flows southwestward through the capital of Ulan-Bator, and merges with the minor Haruuhin River, before joining the Orhon River. The Harea River begins in the Hentiyn Mountains, just northwest of Ulan-bator, and flows to the north before merging with the Orhon near the city of Darhan. The final tributary of the Orhon is the Yöröö River, which originates from a series of minor tributaries in the Hentiyn Mountains. The Yöröö then flows north and joins the Orhon and the Selenge rivers at the border city of Sühbaatar.

Another primary river of north-central Mongolia is the Shishhid River, which originates in the Hövsgöl Mountains. The Shishhid forms Lakes Türga and Dood. After the Shishhid enters the Tuva Region of southern Siberia, it joins with the Yenisey River, which flows north through Siberia and drains into the Arctic Ocean.

In northwest Mongolia, the main river system, the Dzavhan River, is formed by the confluence of three minor rivers: the Dzag, the Buyant, and the Shar Us. These rivers originate on the southern slopes of the Hangayn Mountains before forming the Dzavhan River near the town of Delgar. From this point, the Dzavhan flows northwestward for more than 270 miles (500 km) through the Great Lakes region of Mongolia. Several minor tributaries of this major artery feed many of the lakes of northwestern Mongolia. The Dzavhan terminates in Lake Hyargas by way of Lake Ayrag.

There are three other main rivers that feed the Great Lakes. The Tesiyn River flows from the Sangilen Mountains of southern Siberia into the largest lake in the Great Lakes, Lake Uvs. The Hovd River originates in the Altai Mountains and feeds Lake Har Us. The Hüngüy River, which begins in the Hangayn Mountains, also feeds Lake Ayrag.

In northeastern Mongolia, there are two primary rivers, both originating in the Hentiyn Mountains. The first, the Onon River, flows through Hentiy Province, exits Mongolia, and merges with the Amur River in southeastern Siberia. The Amur forms the border between Russia and China, and eventually empties into the Sea of Okhotsk. The second, and mightier river of northeastern Mongolia, is the Kerulen River. The Kerulen flows for nearly 430 miles (800 km) across Hentiy and Dornod provinces. The Kerulen also flows through the center of the city of Choibalsan before crossing the border into China. Shortly after entering China, the Kerulen forms a large lake, Lake Hulun, before also merging with the Amur River. A minor tributary of the Kerulen, exiting from the southeastern corner of Lake Hulun, is the Orxon River. Shortly after entering extreme eastern Mongolia, the Orxon River drains into Lake Buyr.

The southern and eastern plateau is crisscrossed by hundreds of dry riverbeds. These dry riverbeds are only briefly, but turbulently, filled by seasonal rains. This water drains into salt lakes or into the dry terrain of the Gobi Desert. Much of this water

MONGOLIA GEOGRAPHY

remains subterranean and serves as a source of water to supply the many desert oases.

Lakes. Most of the lakes of Mongolia are found in either the north-central, or northwestern portions of the country. The largest lake in Mongolia, Lake Hövsgöl, is found in the north-central part of the country, and is fed primarily by the Egiyn River, and additionally by countless other smaller streams originating in the Hövsgöl Mountains. There is also a small island, Dalay Huy, found in the south-central part of Lake Hövsgöl. The lake is approximately 80 miles (130 km) long, by 22 miles (35 km) wide, and is known for its large subterranean caves. Lakes Türga and Dood are also found in the Hövsgöl Mountains. These two lakes are fed by the Shishhid River. There are more than 300 smaller lakes in this part of Mongolia.

The northwestern section of Mongolia, known as the Great Lakes, contains more than 300 lakes that are fed by the extensive river systems of the area. The largest lake in the region, Lake Uvs, is located near the border with Russia and is fed by the Tesiyn River and many other streams originating in the nearby mountains. Several other large lakes of the region are Lakes Hyargas, Har, Dörüü, and Har Us. Lake Har Us was at one time much larger, but the former northeastern quadrant is now classified as a rapidly disappearing swamp.

On the northern flanks of the Hangayn Mountains is the Khorgo region. This area is home to numerous lakes of volcanic origin. The three largest lakes in the Khorgo region are Lakes Oygon, Telmer, and Sangiyn Dalay. These lakes are fed by numerous mountain streams as well as by subsurface hot springs.

The only lake of any consequence in eastern Mongolia is Lake Buyr, which is in extreme eastern Sühbataar Province. This lake is fed by the Orxon River, an outflow of Lake Hulun, located directly across the border in northeastern China. The Gobi Desert is devoid of lakes of any size. There are numerous dry lakebeds in the desert, which are only intermittently filled during rainshowers. After the

rain passes, the water either evaporates, or becomes a subterranean source of water for the many oases that are found in the region.

Vegetation. The vegetation and soil patterns reflect the climatic variations of Mongolia. The desert and semidesert areas contain a high concentration of saline. The rest of the country is dominated by a brown or chestnut variety of soil. Vegetation types often change rapidly with altitude or latitude. There are four basic divisions running in latitude from north to south and in altitude from the mountains to the basins and plains: forest-steppe, steppe, semidesert, and desert. Additionally, there are bands of coniferous forests (taiga) and an alpine zone in the higher mountains. The steppes dominate over three-quarters of the land area of Mongolia.

The mountain forest-steppe, which grows thickest in the northern shady slopes, exhibits the widest diversity of flora and fauna. The most widely distributed tree is the Siberian larch, followed by the cedar, spruce, pine, and fir. Deciduous trees include birch, aspen, and poplar. The steppe vegetation zone is best found in the intermontane basins, the wide river valleys, and the sunny southern flanks of the mountains. Vegetation of the steppe includes feather grass, couch grass, wormwood, and many fodder plant species. The steppes are vibrant with bright violet, blue, red, and yellow summer flowers. The taiga is mainly found on the higher elevations of the dark, damp, northern slopes. At higher elevations, the taiga gives way to the thin grasses and occasional flowers of the alpine zone, merging into the bare rocks and rugged glaciers of the summit zone.

Semideserts are found in the Great Lakes depression in the northwest and over the Gobi in the south, giving way to true desert conditions near the southern border. Scarce tracts of saxaul (xerophytic vegetation adapted to very dry conditions) and groves of elm and poplar clusters surround springs or other underground water sources in these areas. The Gobi Desert is a true hammada (rock-strewn desert region), only the extreme east has small areas of sandy desert.

MAJOR CLIMATIC CONTROLS

The Siberian High. This semipermanent wintertime feature is the strongest cold anticyclone in the world. Firmly entrenched in the vicinity of Lake Baikal by late September, the Siberian high dominates the weather of Mongolia until late April. This shallow dome of cold, dry air rarely extends above 850 mb. At its strongest, during December-February, the Siberian high acts as an effective block to all but the most vigorous frontal systems. Arctic air, originating in the Greenland Sea, enters Siberia in the vicinity of Novaya Zemlya and reinforces the Siberian high. In late March, as the high begins to weaken, frontal systems are able to affect the region.

The Asiatic Low. After the vernal equinox, as the days become longer, the intense sunlight warms the Asiatic landmass. The large heat low that forms near 31° N, 68° E anchors the eastern end of a broad-scale, low-level thermal trough. This trough extends from northwestern India across southern Pakistan, Iran, Saudi Arabia, and into the Sahara from May until October. This low is strongest in July and is normally cloud-free in its center. The Pakistani low is responsible for bringing 75 percent of the annual precipitation to Mongolia.

The Azores High. This semipermanent pressure feature, which is centered near the Azores Islands, plays an important role in bringing mid- and high-level moisture into landlocked Mongolia. Even though the Atlantic Ocean is thousands of miles from Mongolia, it is one of the primary sources of available moisture. The Azores high imports moisture into frontal systems entering western Europe. By the time these frontal systems cross the mountains of central Asia, normally only mid- and high-level moisture remains. In July, as the Azores high moves to its mean northernmost position, near 35° N, 30° W, the amount of low-level moisture contained in the frontal systems reaches an annual peak. This saturation allows a larger amount of low-level moisture to reach the mountains of western Mongolia. With the polar jet and the associated storm track situated along the border with China, the westerlies carry moisture

directly from the Atlantic Ocean into western Mongolia. As the Azores high retreats to the south, the moisture source is cut off. By January, the driest month in Mongolia, the Azores high is at its mean southernmost position, near 29° N, 30° W. The polar jet and the ensuing storm track are also shifted south to a position over the Tibetan Plateau.

The North Pacific High. This semipermanent anticyclone is an important factor in the East Asian monsoon system. The seasonal shift in the position of this feature is closely related to the advance and retreat of major rain belts in East Asia. The higher precipitation amounts that occur in eastern Mongolia, the wettest part of the country, are mainly due to the position of these major rain belts. The North Pacific ridge reaches its mean northernmost position, near 30° N, in August. The major rain belt is normally located poleward of the ridge axis. The position of the high is closely related to the activity of the summer monsoon in East Asia. An active summer monsoon can be expected if the North Pacific high shifts farther north and west than normal. An inactive summer monsoon is likely if the high is farther east and south than normal.

Northeast China Lows. These migratory lows are most prevalent in the spring, after the Siberian high weakens and finally dissipates. Frontal systems crossing central Asia, previously blocked by the massive wintertime anticyclone, tend to lose most of their low-level moisture before reaching Mongolia. Once these frontal systems cross Lake Baykal, cyclogenesis occurs over the comparatively warm, moist air of the lake. Lake Baykal is the world's deepest lake—more than 5,250 feet (1,600 meters)—and retains a tremendous amount of heat. These northeast China lows track east-southeastward and usually reach their peak over northeast China. The low-level moisture absorbed by these lows over Lake Baykal is precipitated out over the eastern section of Mongolia and the Hinggang Mountains of northeast China. They then tend to weaken and continue their eastward movement towards Sakhalin Island and the Sea of Okhotsk.

SPECIAL CLIMATIC CONTROLS

Duststorms/Sandstorms. Even though duststorms and sandstorms can occur anytime during the year, the increased number of frontal passages make springtime the primary season for this phenomenon. Duststorms and sandstorms also occur during winter as a result of cold surges from the strengthening Siberian high. The two primary factors required for duststorms/sandstorms are strong solar heating and mean wind speeds greater than 15 knots. The arid soil and sparse vegetation makes the Gobi Desert a prime area for this phenomenon. During the 30 or more sandstorms that occur in the region each year, dust and sand are lifted as high as 13,000 feet (4,000 meters) AGL. Duststorms and sandstorms usually begin up to 12 hours prior to frontal passage and normally end within 36 hours after frontal passage; conditions can last up to 72 hours during exceptionally vigorous frontal passages. Duststorms associated with cold surges normally begin as soon as the sustained wind speed achieves 15 knots and lasts up to 48 hours. Visibility is restricted to near zero for usually 2 hours, but conditions can persist for as long as 24 hours. Sandstorms in the Gobi Desert have far-reaching effects on the territory to the south and east. During the most vigorous Gobi Desert sandstorms, sand is clearly visible on satellite imagery as far away as Japan, Korea, and Taiwan.

Blowing dust and sand are the most common, and the most serious hazards to operations in the southern and eastern plains of Mongolia. Dust is a finer, smaller atmospheric particle that is nearly always present in the deserts. Sand is a larger, more coarse particle that requires greater wind speeds to be lifted and transported. Additionally, stronger winds and longer trajectories will cause sand and dust particles to be lifted to higher elevations. Aircraft downrush raises dust and sand from the desert floor, which reduces visibility in the immediate vicinity of the aircraft. Also, dust and

sand enter engine intakes and cause damage. During severe sandstorm conditions, ablation of windscreens and other aircraft parts can occur. Persistent dust conditions also cause dry skin, sore throat, and cracked lips of personnel. Dust also contributes to radio signal degradation. When windblown particles strike an object a heavy electrostatic discharge may result. The surprisingly high-voltage sparking associated with these electrostatic discharges can pose a hazard to personnel and equipment.

The most-favored locations for blowing dust and sand are found along the southern edge of the Gobi Desert, on the Sino-Mongolian border. The persistent winds blowing across the desert account for the high occurrence of blowing sand or dust. The two stations that record the highest number of days with blowing sand or dust are Tsogt-Ovoo with 72 days and Dalanzadgad with 67 days; both stations are located in the central Gobi Desert. Several other stations in the Gobi Desert and the plains south of the Altai Mountains report more than 40 days of blowing sand or dust each year.

Föhn Winds. Föhn winds most commonly occur in the valleys of the western mountains of Mongolia. The most-favored time of year for föhn winds is from late winter, through spring, but can occur during the fall and early winter. Föhn winds are normally initiated by cold surges from Siberia. As the extremely cold, dense air is forced down the slopes of mountains, the air is warmed adiabatically. The effect on valley locations is profound. Ambient temperatures usually rise as much as 20-25 Celsius degrees. Relative humidities plummet drastically to below 10 percent. Wind speeds suddenly increase with the onset of the föhn. The most favored location for föhn winds is Uliastai, which is located in the western Altai Mountains.

General Weather. Winter is the longest season in Mongolia, lasting an average of 5-6 months. By November, the Siberian high is firmly established and centered between western Mongolia and Lake Baykal in Russia. This shallow dome of cold, dry, continental polar air dominates the climate of Mongolia, bringing predominately stable conditions. The Siberian high is evident as a closed

anticyclone at the 850-mb level and as a ridge of high pressure at 700 mb. Arctic air entering northern Siberia travels across the continent to reinforce the center of the anticyclone. Cold fronts associated with these bursts are very shallow and are greatly affected by topography. The northwesterly flow from the Siberian high is amplified and channeled in the valleys between the major mountain ranges.

Sky Cover. The terrain of Mongolia plays a tremendous role in determining the amount of clouds in each layer. The mean amount of total clouds across the region is 30 to 40 percent. Taken by itself, this figure is actually misleading since the mean amount in the lowest layer is between 5 to 10 percent, and the mean amount is 60 to 70 percent in the middle and upper levels. Figure 5-2 shows the frequency of ceilings below 3,000 feet for selected locations in Mongolia.

Most stations in Mongolia report ceilings below 3,000 feet less than 2 percent of the time. Only a few stations report this category of ceilings greater than 5 percent of the time. Ulan-Gom, located just south of Lake Uvs, reports low ceilings up to 7.4 percent of the time at certain hours. This is the greatest frequency of recorded low ceilings in

Mongolia. The other sites reporting low ceilings greater than 5 percent of the time are located near a sizable body of water—either a large lake or a major river.

In the middle and upper levels, the mid-latitude westerlies prevail. The polar jet is situated over the northern Tibetan Plateau with a long-wave trough extending from western Mongolia to western Tibet. Periodic pulses in the jet stream import mid- and high-level clouds from the Atlantic Ocean moisture source. The arctic jet, situated across southern Siberia to southern Mongolia, is a secondary source of upper-level clouds. Recurrent cold surges from the Arctic Ocean region and intensification of the Siberian high cause the position of the arctic jet and the corresponding low-level front to shift south into southern Mongolia.

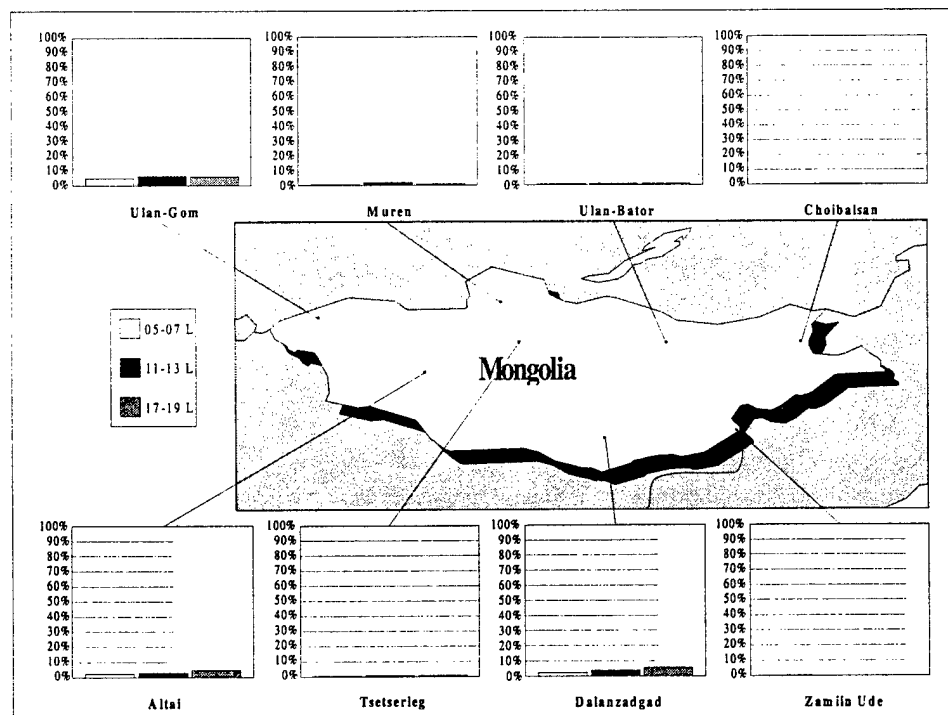


Figure 5-2. January Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. For most locations in Mongolia, winter is a season of excellent visibility. The air is exceptionally dry, clear, and free of any restrictions. Few locations report visibility less than 4,800 meters more than 5 percent of the time. In fact, most Mongolian stations report this reduced visibility less than 2 percent of the time (see Figure 5-3). The cities of Muren and Ulan-Bator have the greatest problems with visibility restriction.

Local terrain and industrial sources restrict the visibility Ulan-Bator, to less than 4,800 meters up to 61 percent of the time. This administrative center of Mongolia is also a center of industry and mining. Most of the population burns coal, wood, and kerosene for residential and business heating during the long winter. Ulan-Bator has an elevation of 4,320 feet (1,316 meters) and is surrounded by mountains between 4,900 and 5,900 feet (1,500 and 1,800 meters) in height. The intense Siberian high acts as a cap and keeps the air stagnant in the valley.

The effect is strongest around sunrise just before the radiational inversion breaks. The visibility rapidly improves after the inversion breaks.

Although the situation at Muren is similar, the frequency of restricted visibility is not as high as it is at Ulan-Bator. Muren reports visibility restricted to less than 4,800 meters 34 percent of the time. Also, the primary restriction to visibility at Muren is not from smoke and haze but from radiative and advective fog. Muren is situated in the Delger River valley at an elevation of 4,000 feet (1,200 meters) and is surrounded by mountains 5,900 to 7,900 feet (1,800 to 2,400 meters) in height. Several small lakes in the vicinity provide moisture for fog formation. Additionally, Muren sits at the southern end of a valley, approximately 60 miles (90 km) from Lake Hövsgöl. The cold northerly winds from the Siberian high blow directly over the comparatively warm waters of Lake Hövsgöl and advect fog into Muren. Visibility is at a minimum just before the radiational inversion breaks.

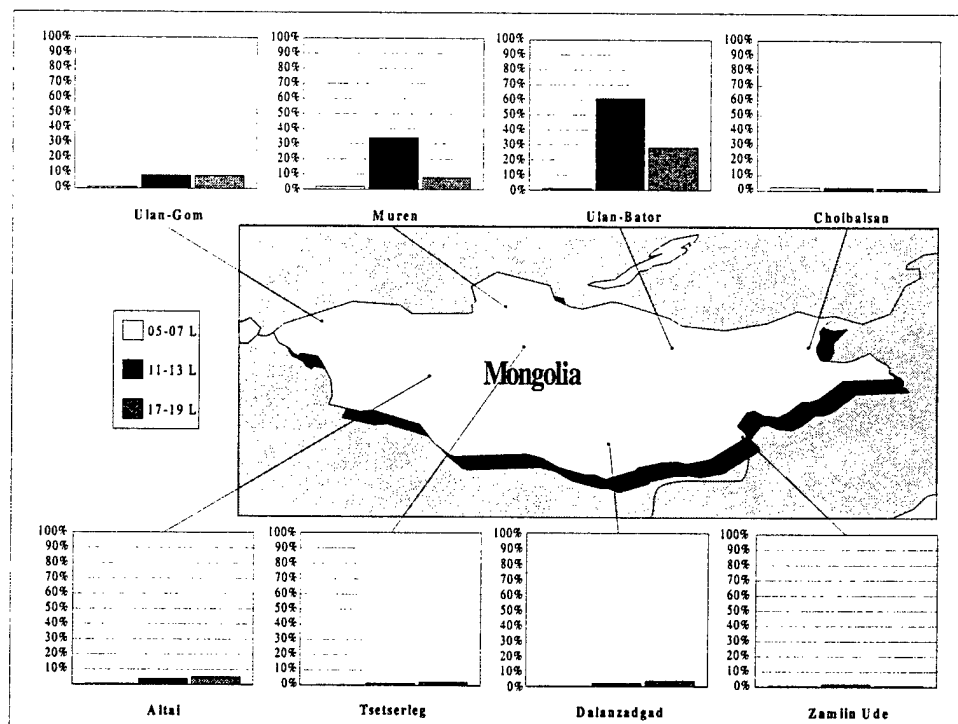


Figure 5-3. January Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Surface winds in Mongolia are highly determined by the strength and position of the Siberian high. Local terrain and diurnal effects also play an important role in determining wind speed and direction. Mongolia, in the southeast quadrant of the Siberian high, has predominately northwesterly flow in the winter. The northwest-southeast orientation of the Altai and Hangayn mountain ranges makes these locations conducive to channeling and downslope effects.

Wind speeds are typically higher in the earliest and the latest parts of the season. In early November and late March, the Siberian high is either setting up or in the process of weakening. It is during these times that Mongolia is still susceptible to the influences of migratory frontal systems. From mid-November until mid-March, especially during December and January, the Siberian high is firmly entrenched and blocks Mongolia from passing frontal systems. Under the influence of the strong Siberian high, most Mongolian locations record their lowest mean wind speeds and the highest annual frequency of calm winds.

Mean wind speeds vary by location, but for the most part, speeds are higher in the afternoon than during the nighttime hours. Winds are typically calm under the strong nighttime radiational inversion and increase to the 10-15 knot range immediately after the inversion breaks in late morning. The highest wind speeds normally occur in midafternoon and die off as the inversion reforms after sunset.

The highest recorded wintertime wind speeds are found in the highest elevations of the Altai Mountains. Both Altai and Ulgi have recorded extreme maximum winds of 66 knots. Also, the highest station in the Hangayn Mountains, Galut, has an extreme maximum wind of 64 knots. Extremely high record wind speeds are also found

in the barren stretches of the Gobi Desert. Zamiin Ude also recorded an extreme maximum of 66 knots. In south-central Gobi, Tsogt-Ovoo recorded an extreme wind of 60 knots. In contrast, sheltered by surrounding mountains, Ulan-Bator recorded the lowest extreme maximum wind in the nation with a wind speed of only 37 knots.

Terrain and diurnal effects are quite noticeable during the winter months. This is because the Siberian high blocks the rare influences of all but the strongest migratory pressure systems. Of particular note is the 06Z wind rose for Altai shown in Figure 5-4. The most prominent feature of the wind rose is the high percentage of westerly winds. Even though the percentage of time southwesterly winds are recorded is relatively low, this is the favored wind direction for wind speeds in excess of 35 knots. This is a reflection of higher wind speeds in advance of passing frontal systems.

Most Mongolian stations record a high percentage of calm winds during the winter months. The city of Hovdo is located near the center of the Siberian high in far western Mongolia. This station is also protected by surrounding mountains and records calm winds 95 percent of the time in the dead of winter. In contrast, the city of Underhan records calm winds less than 10 percent of the time. Underhan's wind rose shows a strong channeling effect, averaging southwesterly winds up to 70 percent of the time. There is a nearly constant breeze of between 6 and 15 knots at this site. This effect is caused by Underhaan's location on the southwest-northeast flowing Herlen River. Additionally, the Herlen lies in a valley with a mean elevation of 1,000 meters and is surrounded by 1,300- to 1,700-meter hills. Figures 5-5 and 5-6 depict the prevailing midafternoon and late night wind directions and range of speeds for eight selected Mongolian stations.

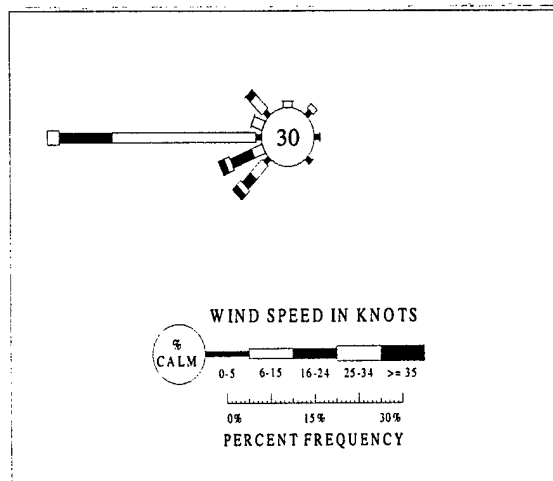


Figure 5-4. November 06Z Surface Wind Rose for Altai. The wind rose depicts the westerly channeling effect, as well as the favored southwesterly direction for higher wind speeds.

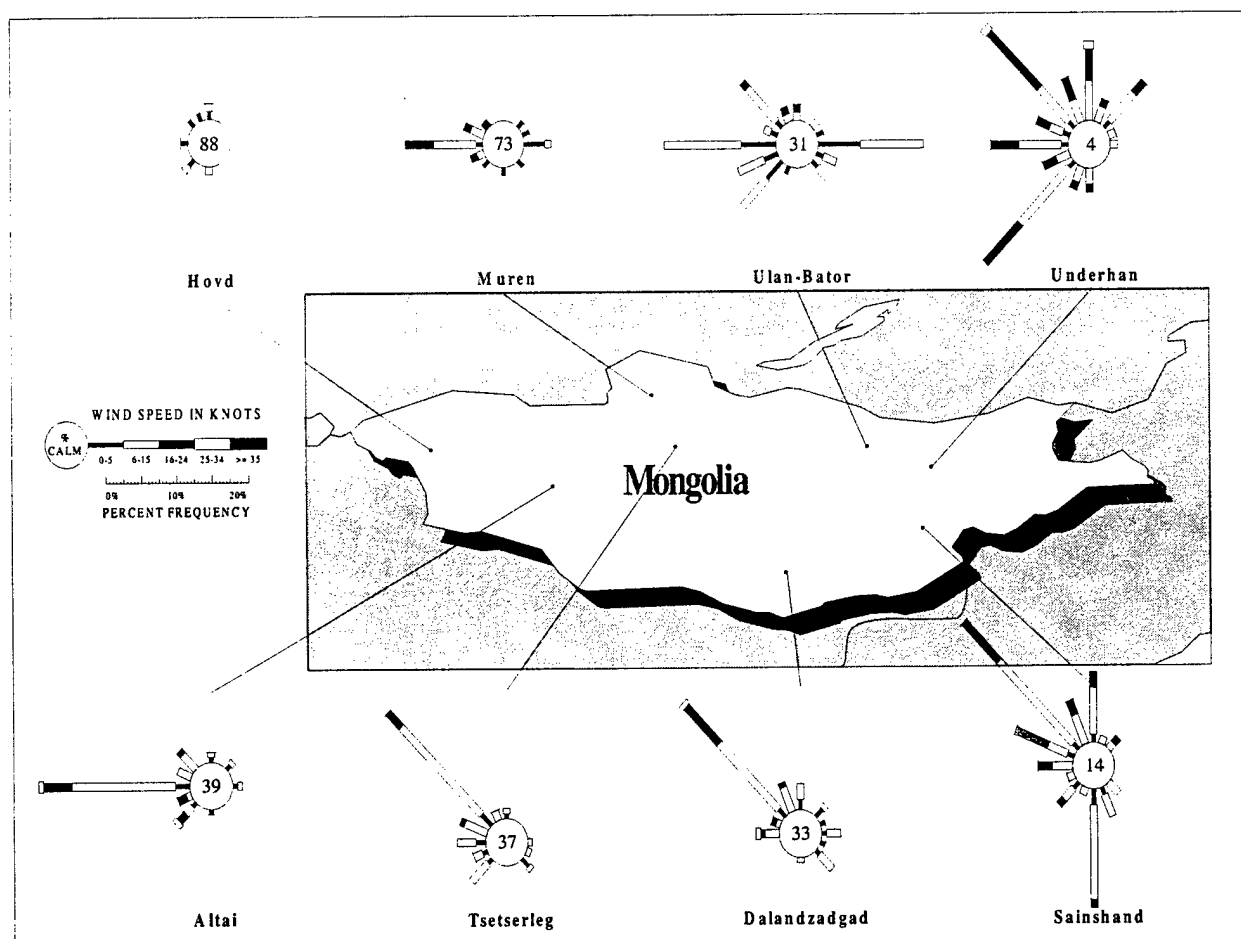


Figure 5-5. January 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on frequency and location.

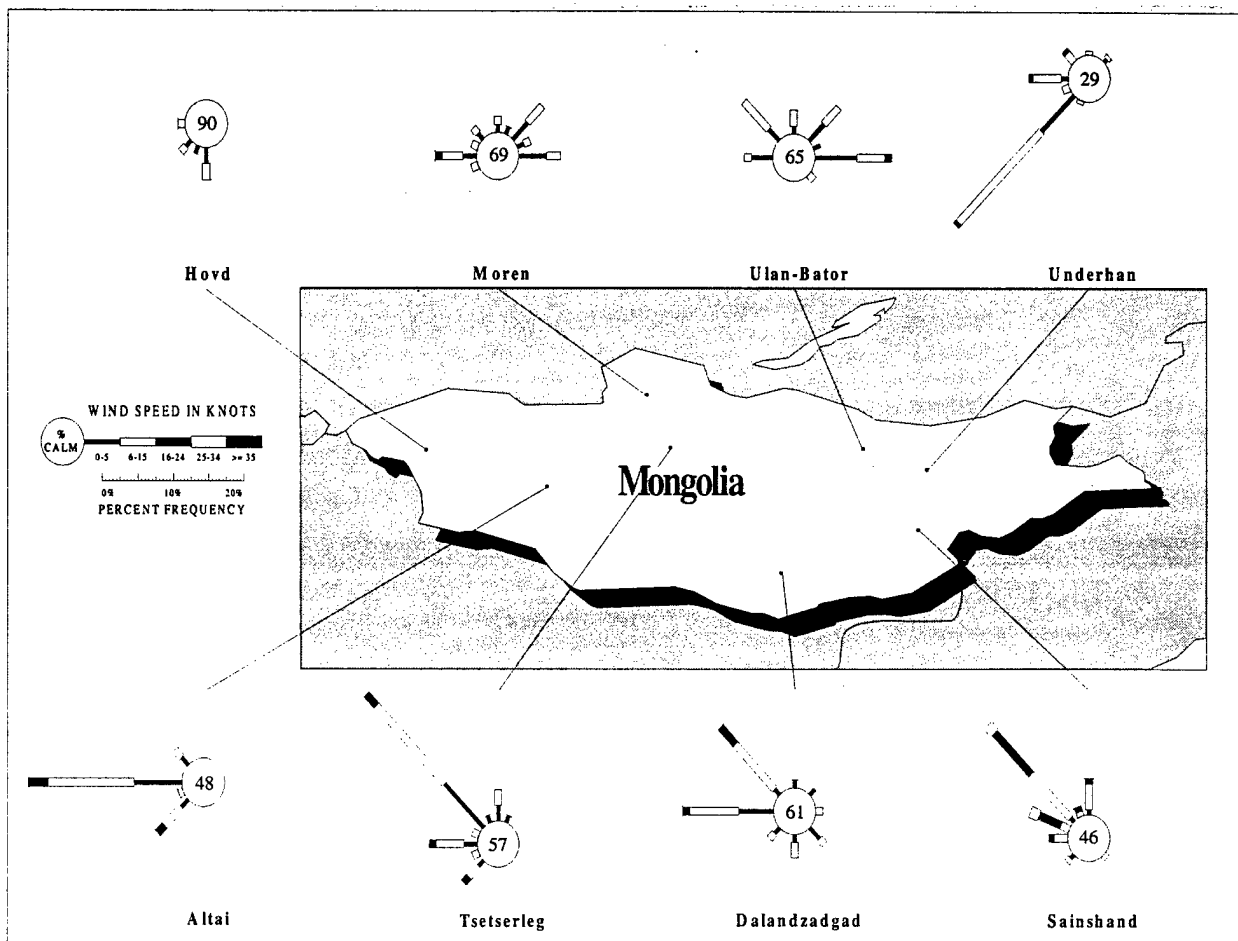


Figure 5-6. January 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on frequency and location.

Upper-Air Winds. At the onset of winter across Mongolia, the main polar front jet is situated over southern Tibet. The polar jet is best depicted at 200 mb, with average wind speeds approaching 100 knots. The arctic front jet is weakly reflected at 300 mb as a band of 50 knot winds over eastern Mongolia. The Siberian high, still undergoing anticyclogenesis on the surface, is shown as a weak ridge aloft over western Mongolia.

At the height of winter in January, the polar jet is at

its southernmost position across southern China. The arctic jet is best seen at 100 mb over eastern Mongolia as a band of 50-75 knot winds before merging with the polar jet over Japan. The intense surface Siberian high is reflected as a strong ridge aloft. Figure 5-7 shows upper-air wind roses for Ulan-Bator.

By March, the Siberian high weakens, and the polar jet moves from southern to central Tibet. The arctic jet is reflected as a 50 knot band of winds over eastern Mongolia at the 200-mb level.

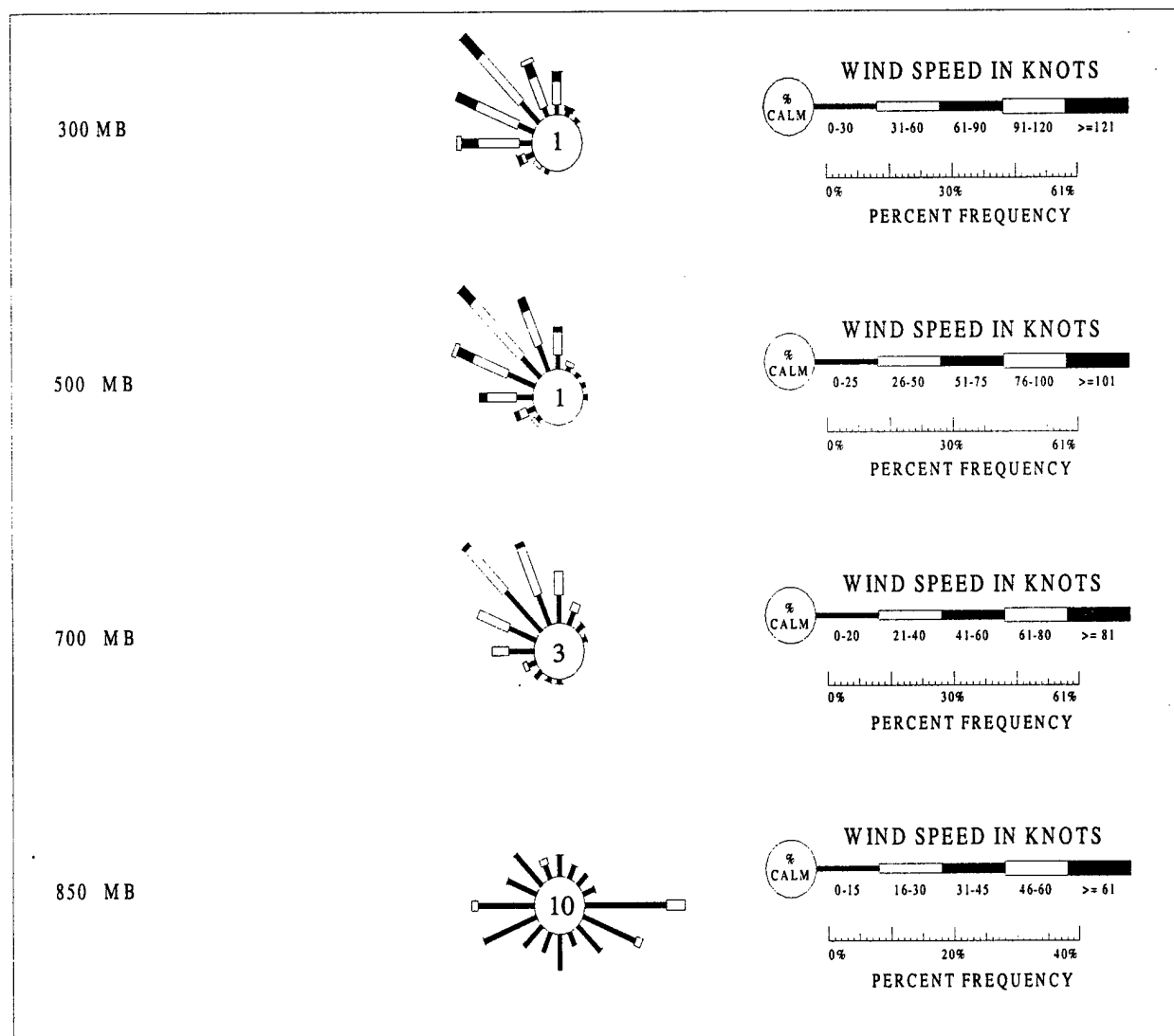


Figure 5-7. January Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Ulan-Bator. Note: Each wind rose has a tailored legend.

Precipitation. Winter is a time of extremely sparse precipitation across Mongolia. The Siberian air mass is extremely dry, stable, and generally not favorable for heavy precipitation. The only type of precipitation that usually occurs during winter is light snow from stratiform clouds. During each of the five winter months most of the nation records less than 5 mm of precipitation. Only the northern slopes of the Hentiyn Mountains, northeast of Ulan-Bator, record more than 10 mm of precipitation for each of the winter months. Figure 5-8 depicts the mean monthly precipitation for January in Mongolia.

The Hentiyn Mountains are a favored location for snowfall because their ridgeline is nearly perpendicular to the prevailing northwesterly windflow. The windflow in this region contains a greater amount of moisture since it comes across the relatively warm surface of Lake Baykal. Even in the depth of winter when the surface of the lake freezes, it is still much warmer than the surrounding air mass. The extreme depth of the lake transports heat from the bottom of the lake to the surface. This moisture is advected directly into the mountains of north-central Mongolia. Precipitation is nearly constant, although still light in this region. Ulan-Bator records an annual mean of 61 days of snowfall. Barunhara, just northwest of the Hentiyn, records 50 days of snowfall each year. Other favored locations for this type of upslope

snowfall are the stations on the northern faces of the Hangayn and Altai mountain ranges. Tsetserleg records 50 days of snowfall, while Altai and Uliastai record 47 and 44 days of snowfall each year, respectively. Conversely, stations located on the lee side of mountain ranges record a lower number of snowfall days each year.

Bayanhongor and Galut, located on the southern slopes of the central Hangayn Mountains, receive 25 and 28 days of snow, respectively. Despite high elevations of 5,900 feet (1,800 meters), both locations record a very low number of snowfall days. Additionally, Bayan Suma, located barely 80 km southeast of Ulan-Bator, only records 31 snowfall days each year. Even though this station is less than a degree of latitude away from the capital, Bayan Suma is on the southern slopes, or lee side of the Hentiyn Mountains.

The stations with the lowest number of snowfall days are found in the southern and eastern Gobi Desert. The stations in the Gobi record about 20 days of snow each year, with Zamiin Ude recording only 14 snow days each year. Precipitation is extremely light in the Gobi. The entire region records less than 5 mm of precipitable water for each of the winter months. Figure 5-9 shows the mean number of January snowfall and rainfall days for selected locations across Mongolia.

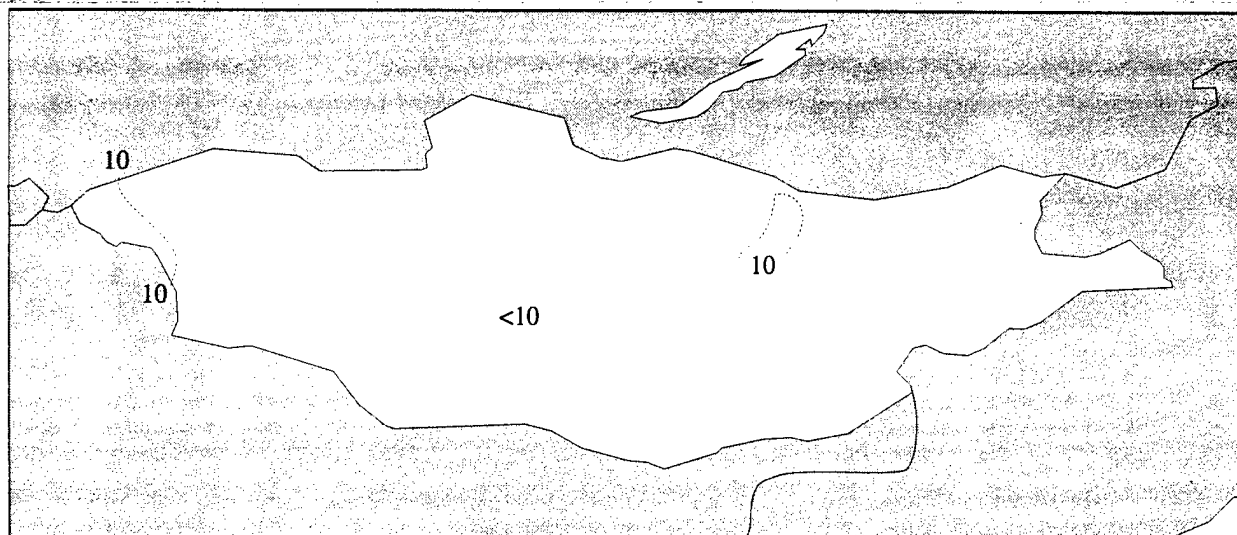


Figure 5-8. January Mean Precipitation (mm). The isopleths show the sparse amount of precipitation that occurs during the Mongolian winter.

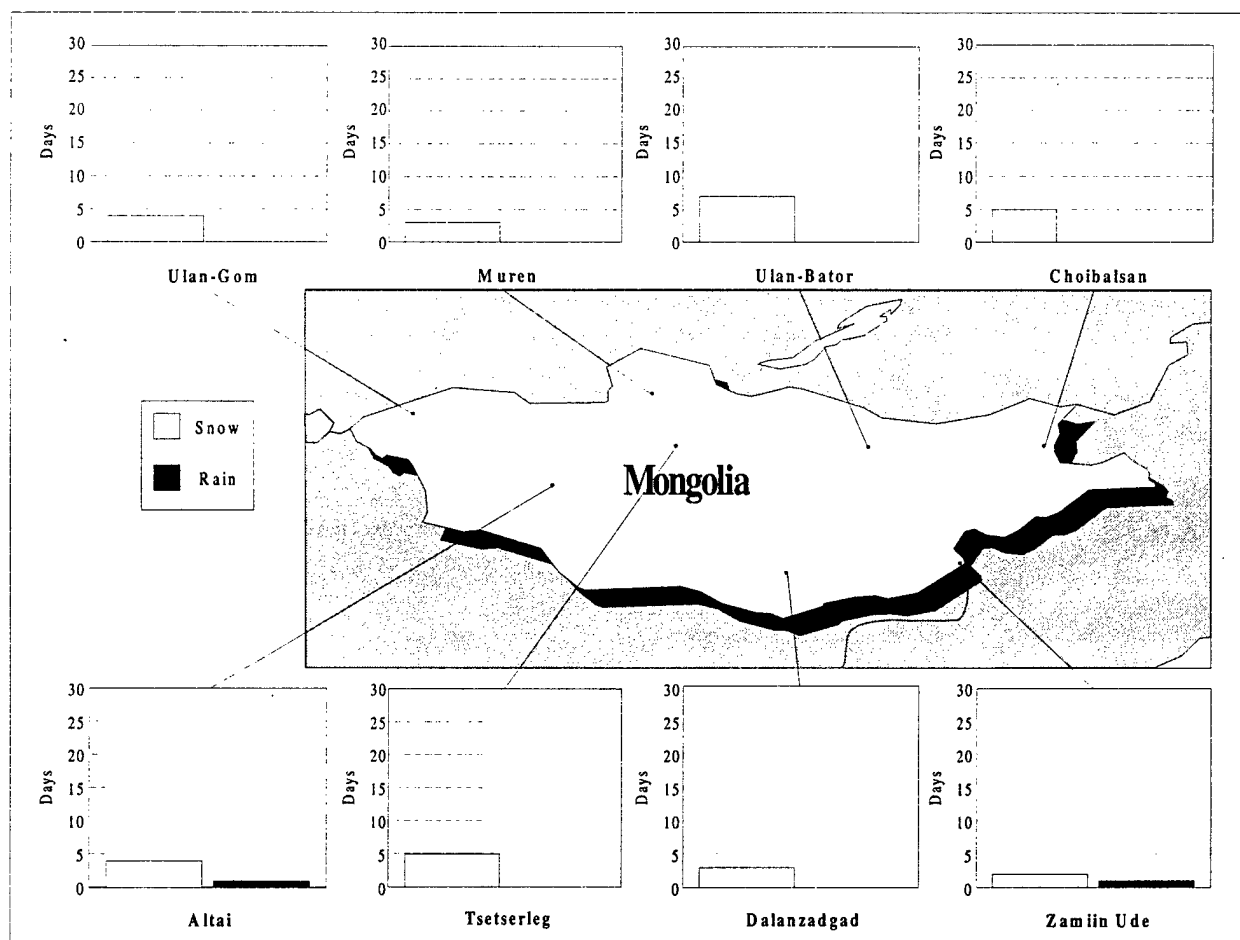


Figure 5-9. January Mean Number of Snowfall and Rainfall Days. The graphs show the mean number of days with snow for selected locations across Mongolia.

Temperatures. Mongolian winters are brutally cold under the full brunt of the Siberian high. The prevailing northerly flow brings the coldest air mass in the Northern Hemisphere into Mongolia. This air mass is also extremely dry and stable. The dry nature of central Asia allows for a large diurnal and annual temperature variation. The difference between mean daily maximums and minimums averages from 14-22 Fahrenheit (8-12 Celsius) degrees. Most Mongolian stations average an annual temperature variation between wintertime mean daily minimums and summertime mean daily maximums of at least 90 Fahrenheit (50 Celsius) degrees. Ranges between annual extremes are much greater, in some instances exceeding 144 Fahrenheit (80 Celsius) degrees.

The strong radiational inversion associated with the Siberian high has an interesting interplay with the terrain of Mongolia. The inversion is formed by extensive cooling of valley and basin floors and by heating of air immediately along mountain slopes. Frequently, the air is up to 36 Fahrenheit (20 Celsius) degrees warmer at altitudes of 3,280 feet to 4,920 feet (1,000 to 1,500 meters) above the valley or basin floor. Above 4,920 feet (1,500

meters) AGL, the temperature cools dry adiabatically.

In northwest Mongolia, mean daily minimums are coldest near the center of the Siberian high. Warmest temperatures are found in the eastern and southeastern regions of the Gobi Desert. Minimums range from -33°F (-36°C) at Ulan-Gom to -2°F (-19°C) at Dalanzadgad and Arbaiher. Mean daily maximums are also lowest in the northwest and warmest in the Gobi. Mean maximums range from -17°F (-27°C) at Ulan-Gom to 18°F (-8°C) at Dalanzadgad. These two stations are the extremes. The vast majority of Mongolian sites have mean daily maximums in the 14°F (-10°C) to 0°F (-18°C) range. Figures 5-10 and 5-11 depict mean maximum and mean minimum temperatures for January.

Hatgal recorded the lowest extreme minimum temperature in Mongolia of -56°F (-49°C). Ulan-Gom and Muren came in a close second, each with an extreme minimum of -54°F (-48°C). The extreme maximum January temperature was 55°F (13°C), recorded at Dalanzadgad.

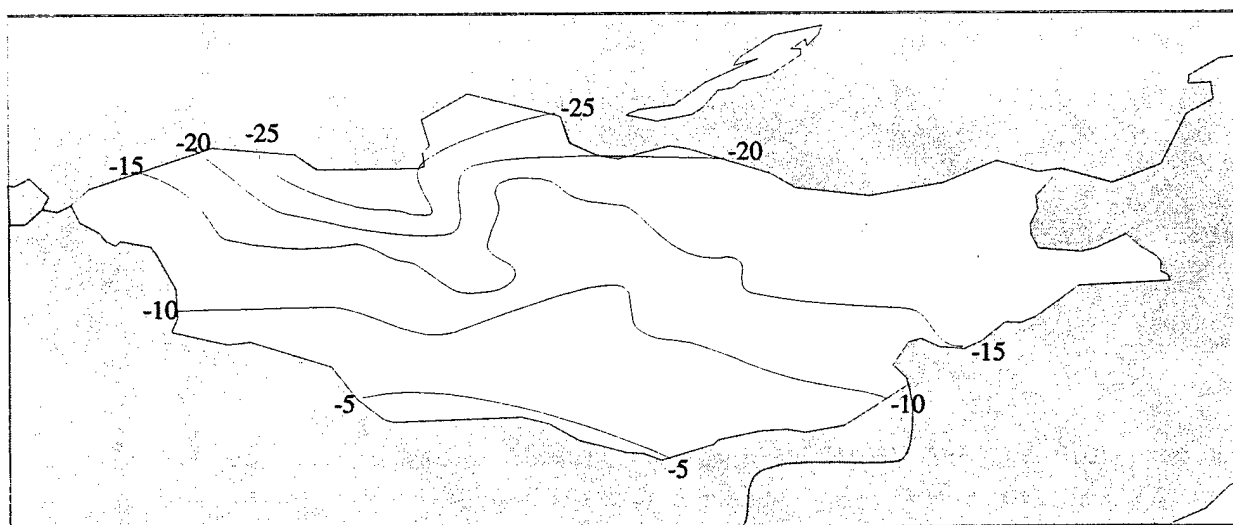


Figure 5-10. January Mean Maximum Temperatures (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

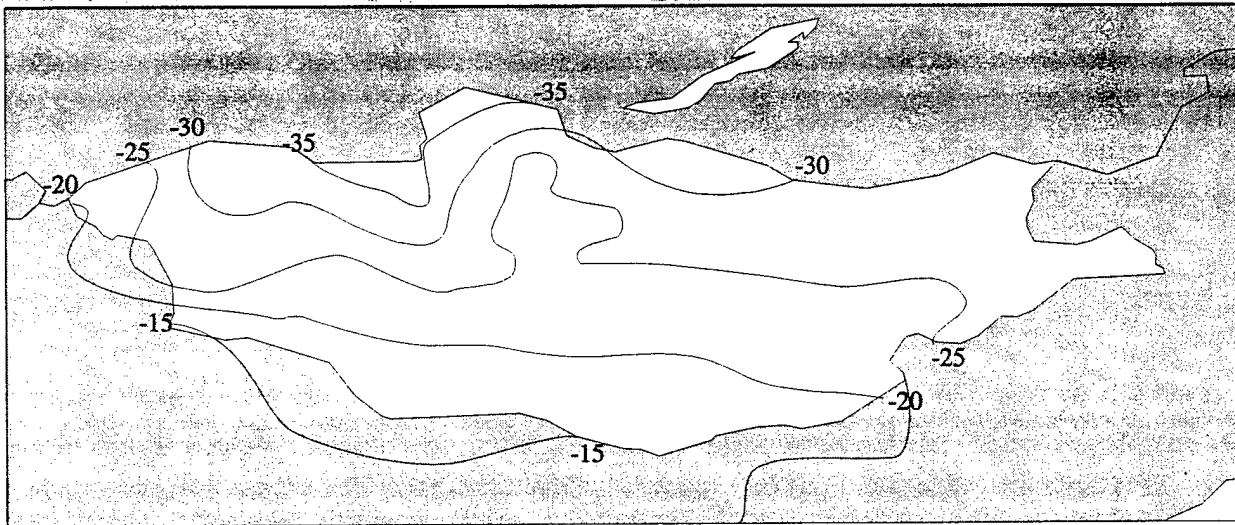


Figure 5-11. January Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

Hazards.

Aircraft Icing. Icing is mainly restricted to altocumulus and altostratus layers found in the migratory frontal systems that pass through the region from the distant Atlantic Ocean moisture source. Low-level moisture is normally too scarce to allow any more than a trace of icing. Light-to-moderate rime icing occurs in the light but nearly continuous snowfall found over the Altai, Hentiyn, and Hangayn mountains.

Turbulence. Strong post-frontal northwesterly winds blow perpendicular to the southwest-northeast oriented Hentiyn Mountains and produce conditions conducive to mountain wave turbulence. With sufficient moisture available, altocumulus standing lenticular (ACSL) clouds will form on the lee side of the ridge line. However, since the

air is usually too dry, ACSL will not normally be visible. However, moderate-to-severe turbulence will still exist, up to 47 to 62 miles (75-100 km) downstream and up to an altitude of 45,000 to 95,000 feet (15-30 km). Additionally, strong winds funneled through the valleys of the Hangayn and Altai mountains produce moderate-to-occasionally severe turbulence.

Usually on the second day after the frontal passage, the mountain wave breaks down. The winds shift from a northerly direction to an easterly or southeasterly direction. Once the perpendicular component decreases, the mountain wave and the resulting turbulence dissipates. The peak time for mountain wave occurrence is from late winter into spring. This ties in with the weakening of the Siberian high, which opens the storm track into Mongolia.

Trafficability. Mongolia is a country of high elevations with three major topographic areas. There areas include the following: (1) massive, forested, high mountains to the center, north, and west, (2) large basins between the mountains, and (3) an upland plateau across the south and east that consists of desert, semidesert, and upland steppe.

The mountains of the west are the highest and most rugged. The northern and central mountains have characteristically long, gentle slopes and crests covered with large, alpine pastures. The higher parts are very rough and rugged. With a few exceptions, movement in these mountains is unsuitable at all times because of the steep, rugged terrain. The exceptions are the gently sloping pastures. Here the soils are shallow to moderately deep and are mainly coarse to medium-grained or a mixture of both. Movement in these areas is fair when the soils are dry and not snow covered.

In the intermontane basin areas, slopes vary. They are mostly gentle to rolling slopes. Soils are predominantly deep and are a mix of coarse and fine-grained. When dry, movement conditions are fair to poor.

Most of the southern part of the country is rolling desert plain. This area is part of the great Gobi, which is mainly stony desert. Dunes and sand plains occur in the western and southern portions of this region. Various sized salt flats are scattered throughout. Soils are mainly coarse-grained. Fine-grained soils occur in salt flats. Movement conditions are fair to good except in sand dunes and in locations where the plain is broken by heavily dissected ranges.

The east part of Mongolia is rolling to hilly steppe plains that become flatter in the extreme east. Soils are moderately deep to deep and range from coarse to fine-grained. Movement conditions are fair to good.

General Weather. Spring is a short transition season from the cold, dry days of winter to the warm, cloudy days of summer. After the vernal equinox in late March, the great landmass of central Asia begins to warm. In turn, the dominating Siberian high weakens and eventually disappears. The removal of the blocking high allows migratory frontal systems to enter and affect Mongolia. The majority of these systems originate in the north Atlantic and travel across Europe and central Asia before reaching Mongolia. By the time these systems reach Mongolia, they contain only mid- and high-level moisture. The low-level moisture is

normally dropped over the mountains of eastern Asia and southern Siberia. As the sun begins to move north, the polar jet transitions poleward from central Tibet to a position just south of the Sino-Mongolian border. This storm track brings dry lows through the southern Gobi Desert; this causes powerful, large-scale sandstorms. The arctic jet weakens and moves north into south-central Siberia. Fronts found on this storm track are normally dry until they cross Lake Baykal, there they undergo cyclogenesis and pick up low-level moisture; a large amount of this moisture is deposited as rain or snow in the Hentiyn Mountains of northeastern Mongolia.

Sky Cover. Spring is a time of transition from the stratiform clouds of winter to the cumuliform clouds of summer. In early spring, more clouds occur in the north than in the south because the storm track is situated north of Mongolia. Even though there is an abundance of low-level moisture located with migratory lows, these frontal systems usually only bring mid- and high-level cloudiness to Mongolia. As spring progresses, the storm track migrates slightly poleward into Siberia. Mean cloudiness in northern Mongolia increases due to the increased moisture content of the frontal systems. Moisture from the Atlantic and the Arctic oceans becomes more accessible as the season progresses. The Azores high moves slightly poleward, introducing more moisture into the storm track. Additionally, the Arctic Ocean ice begins to melt, opening the second major source of moisture for the region. Moisture from the Arctic moves unfettered into the storm track across the flat expanse of central Siberia.

By late spring, the atmosphere is sufficiently moist and unstable for afternoon convection to occur. Cloudiness is more likely to occur on the windward

slopes of mountain ranges because of orographic lifting. Mountain tops and ridgelines are usually cloud-covered during afternoon hours. Mean cloud coverage is normally at a diurnal minimum near midnight and at a diurnal maximum in the late afternoon. Mean total cloud coverage reaches an annual peak in late spring, with afternoon cloudiness averaging 55-75 percent sky coverage.

The progression of the season also brings a corresponding increase in the frequency of ceilings below 3,000 feet. Stations found on the windward slopes of mountains, in river valleys, or near large lakes are most prone to low ceilings. Tsetserleg, Muren, and Underhan report ceilings below 3,000 feet between 20 and 30 percent of the time. There is also a diurnal maximum for these ceilings in the late afternoon, and a diurnal minimum near midnight. Stations in the Gobi Desert and on the lee side of mountain ranges report the lowest frequency of low ceilings. Bayan Suma, Choir, Sainshand, and Zamiin Ude all report these ceilings less than 5 percent of the time (see Figure 5-12).

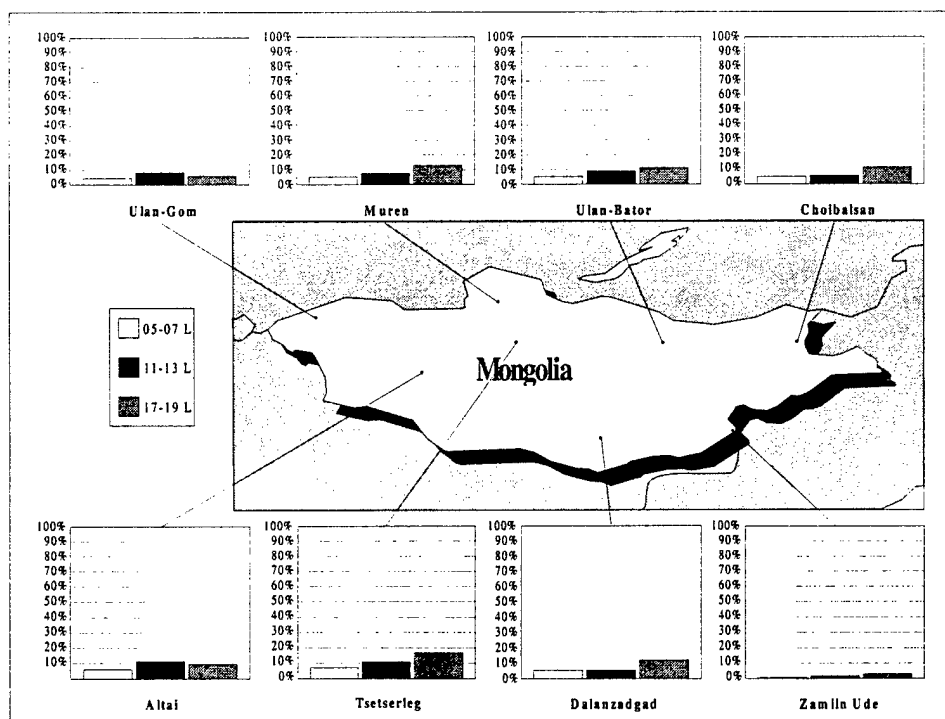


Figure 5-12. April Ceilings below 3,000 Feet. The graphs show a breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Spring is a time of excellent visibility across most of Mongolia. The vast majority of stations report visibility less than 4,800 meters less than 5 percent of the time. The occurrence of fog decreases and is mainly restricted to locations near large lakes and major rivers. The occurrence of snowfall decreases and becomes only a minor impediment to visibility. Snowfall only occurs in the northern regions of the nation and at the highest elevations of the Altai and Hangayn mountains.

Across the southern and eastern sections of Mongolia, blowing dust and sand are the main causes of reduced visibility. The occurrence of blowing sand or dust in the Gobi is nearly double that found in winter. For example, Tsogt-Ovoo averages nearly 24 days of blowing sand or dust during the 60 days of the spring transition. Dust

is nearly always suspended in the atmosphere in the Gobi and the eastern plateau. Visibility in these areas is nearly always restricted to less than 9,000 meters but rarely less than 4,800 meters.

After the Siberian high weakens and disappears, the visibility at Ulan-Bator gradually improves during the spring transition. However, the capital still reports visibility less than 4,800 meters up to 38 percent of the time (at 08L) in April and 22 percent in May. Smoke, fog, and haze continue to be the major contributing factors to the reduced visibility at Ulan-Bator. The surrounding terrain also contributes to the poor visibility in the capital by keeping these restrictions trapped in the immediate area. Figure 5-13 shows the frequency of visibility less than 4,800 meters for selected locations across Mongolia.

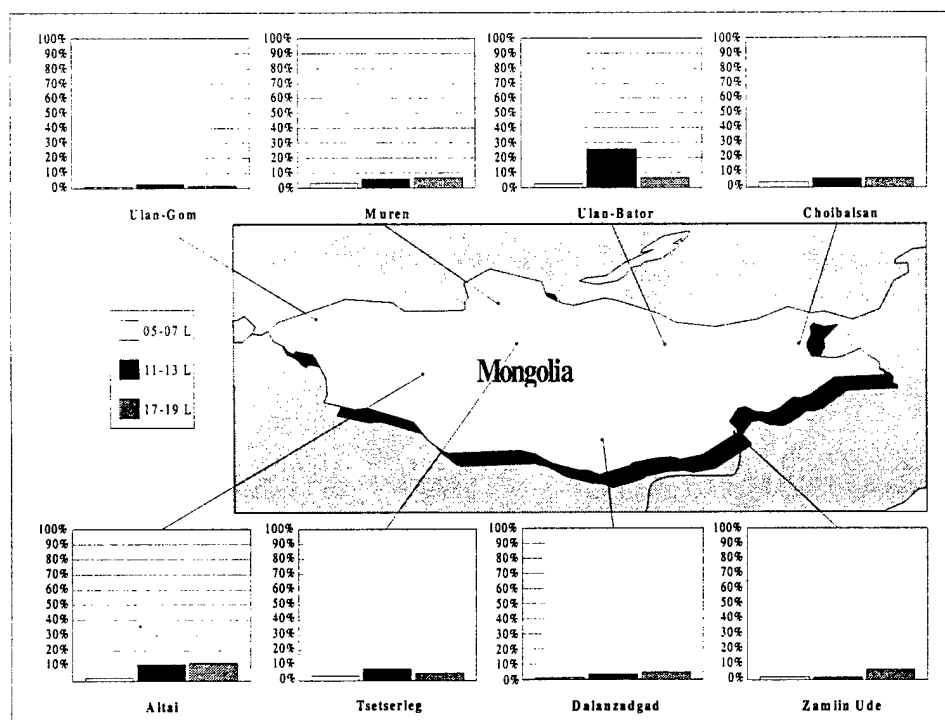


Figure 5-13. April Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Terrain continues to play a large role in determining surface wind conditions in Mongolia. Migratory frontal systems, previously blocked by the Siberian high, now pass unimpeded through the region. Even though the main storm track is north of Mongolia, the southern ends of the fronts have a strong effect on the winds in Mongolia. The storm track associated with the polar jet, situated just south of the border in northern China, also has a tremendous impact on the winds in the Gobi Desert and the eastern plateau regions.

Channeling and downslope winds continue to dominate the mean wind direction at Altai and

Dalanzadgad. The extreme wintertime channeling at Underhan is now moderated by the influence of passing systems. Hovd continues to record the lightest winds of any location in Mongolia; calm winds are reported between 70-80 percent of the time. The eastern plateau and the Gobi Desert are the windiest parts of Mongolia. Numerous locations in these areas have reported extreme maximum winds in excess of 60 knots. Maximum winds of 66 knots have been reported at Bajndelger, Choibalsan, Mandalgovi, and Sainshand. Figures 5-14 and 5-15 show wind roses for eight selected Mongolian sites.

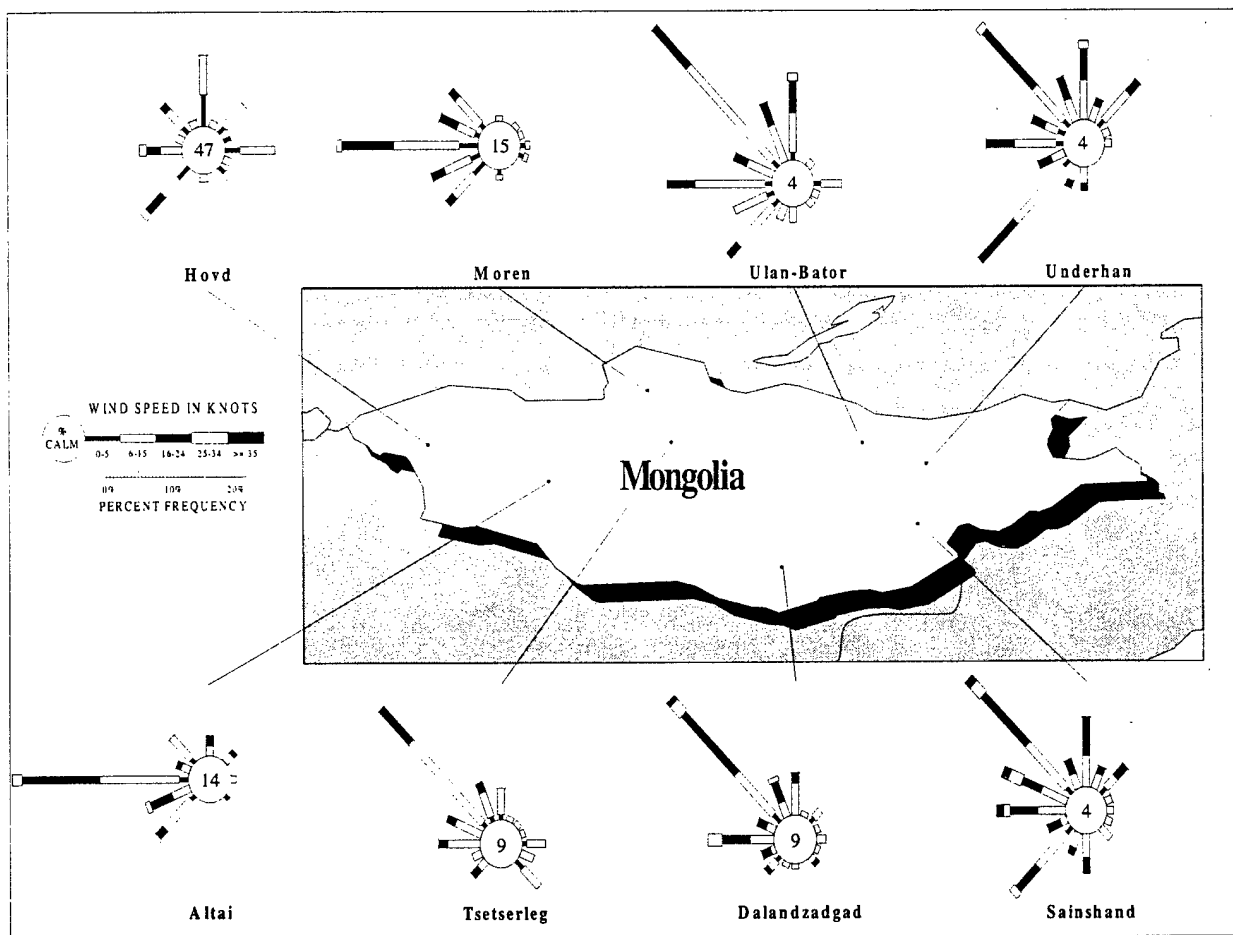


Figure 5-14. April 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on percentage frequency and location.

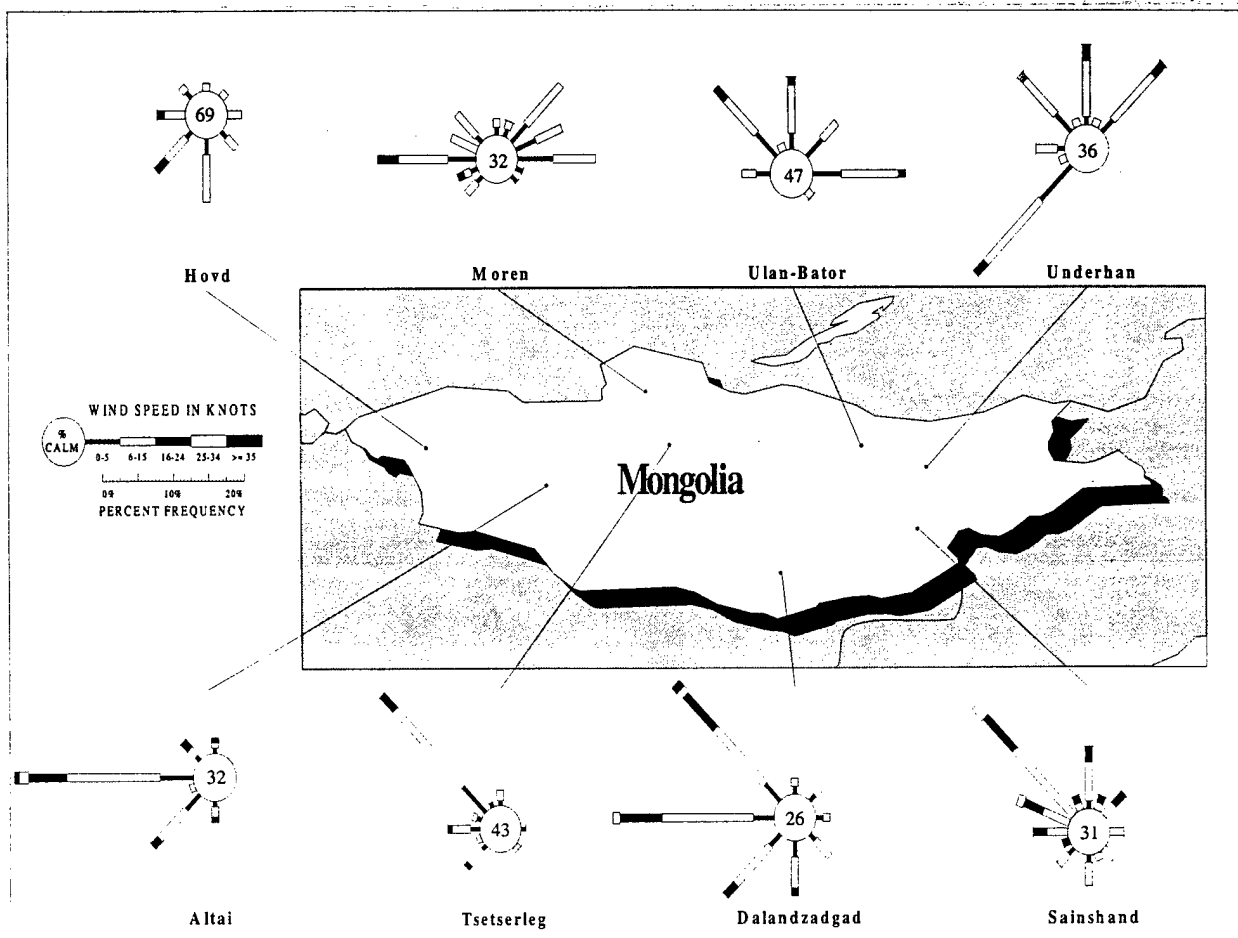


Figure 5-15. April 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on percentage frequency and location.

Upper-Air Winds. As Mongolia enters spring, the arctic jet weakens and moves from east-central to northeastern Mongolia, while the polar jet rapidly migrates from central Tibet to just south of the Sino-Mongolian border. By late spring, the Tibetan 200-mb anticyclone develops, and the polar jet moves into southern Mongolia. Mean wind directions are

either westerly or northwesterly from 700 to 300 mb. The 850-mb winds are affected by local terrain and closely resemble surface winds. In fact, the 850-mb level is on the surface most of the time at Dalanzadgad. Figure 5-16 shows upper-air wind roses for Ulan-Bator.

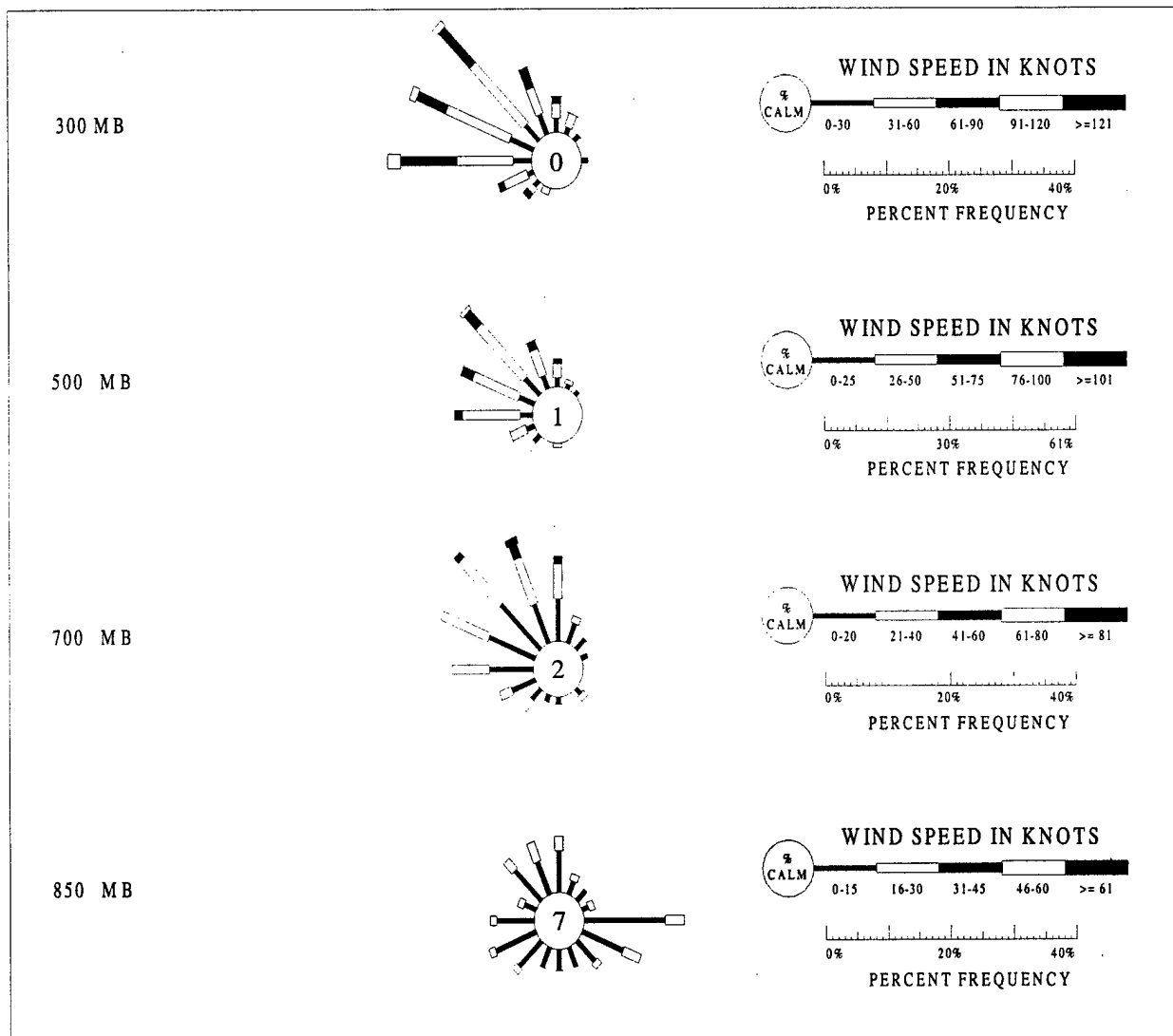


Figure 5-16. April Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Ulan-Bator.

Spring

Precipitation. Most of Mongolia records between 5 and 25 mm of mean monthly precipitation for both April and May. The greatest concentrations of precipitation are found in north-central Hangayn and on the northern slopes of the Hentiyn Mountains. These small areas, found northeast of Ulan-Bator and east of Uliastai, average between 25 and 50 mm of precipitation. The driest areas of Mongolia are the southern Gobi Desert and the Great Lakes region of northwestern Mongolia. These two areas average less than 5 mm of precipitation during both April and May (see Figure 5-17).

Precipitation totals for spring months are not much higher than recorded during the winter. Also, the mean number of days with precipitation for spring is only slightly higher than the average during winter. In early April, most of Mongolia still records a higher number of snow days than rain days. By May, however, the situation reverses and only stations in the far north and at the highest elevations of the mountains record any snow days. Figure 5-18 shows the mean number of days with snow and rain for selected Mongolian stations in April.

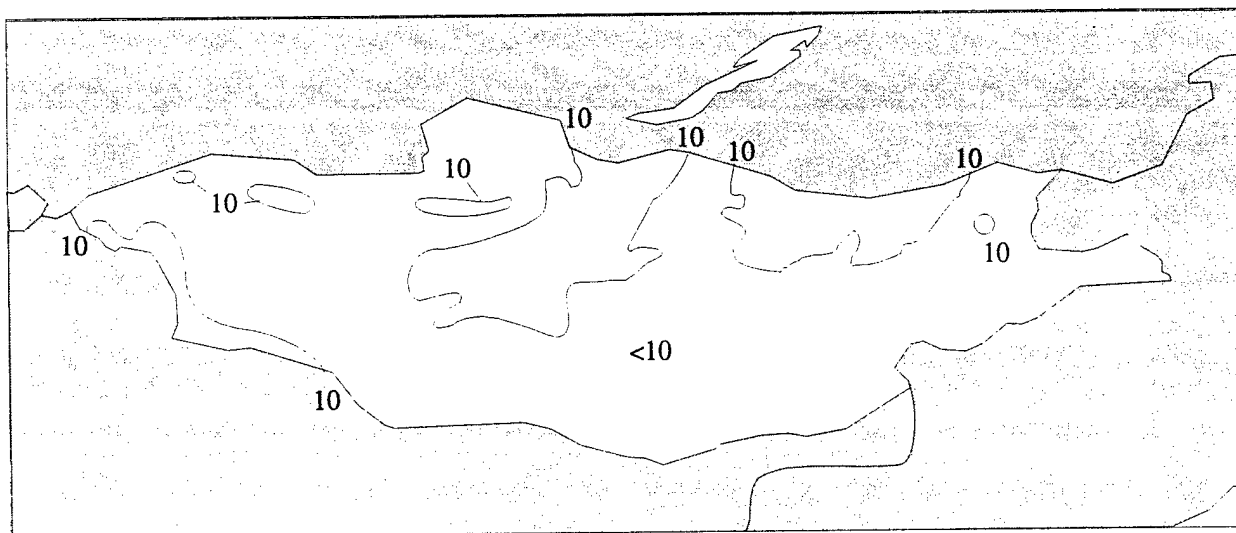


Figure 5-17. April Mean Precipitation (mm). The isopleths show the largest precipitation totals occur in the vicinity of the Hentiyn and Hangayn mountains.

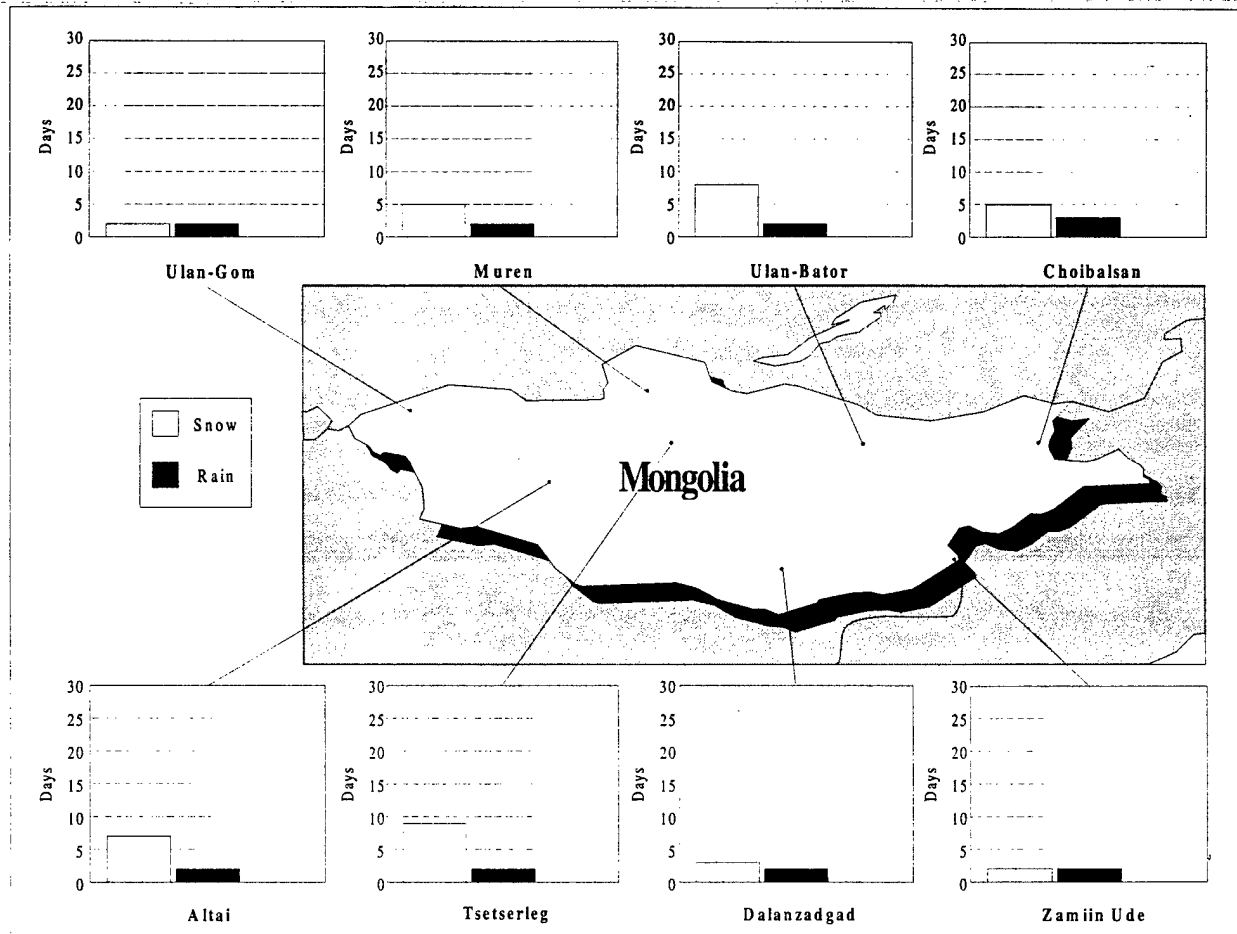


Figure 5-18. April Mean Snow and Rain Days. The graphs show the mean number of days with rain and snow for selected locations across Mongolia.

Temperatures. Once spring begins, the large Mongolian landmass rapidly warms under the increased sunshine. April mean maximum temperatures are above freezing for all stations, but morning lows are still below freezing. By May, mean daily minimums for every station, with the exception of Hatgal, are above freezing.

The coolest sections of Mongolia are in the mountains and the extreme north. Hatgal has the lowest average daily maximum, 39°F (4°C), and minimum, 14°F (-10°C) of any station in Mongolia during the month of April. The warmest regions of Mongolia are the Gobi Desert and the eastern plateau. Located in the southeastern Gobi Desert, Zamiin Ude is the warmest location in Mongolia with a mean daily maximum of 55°F

(13°C). Several stations in the Gobi share the warmest mean daily minimum, a temperature of 32°F (0°C). Figures 5-19 and 5-20 outline the mean daily minimums and maximums for April.

Altai recorded the extreme minimum temperature of -24°F (-31°C) for spring. During spring, extreme minimum temperatures are caused by late cold surges from the dissipating Siberian high. The extreme maximum springtime temperature of 104°F (40°C) was recorded at Barunhara and Mandalgovi. The exceptional range in seasonal extremes, 128 Fahrenheit (71 Celsius) degrees and the large diurnal temperature variation are caused by the arid Mongolian air mass. On average, Mongolian stations have a diurnal temperature variation between 18-27 Fahrenheit (10-15 Celsius) degrees.

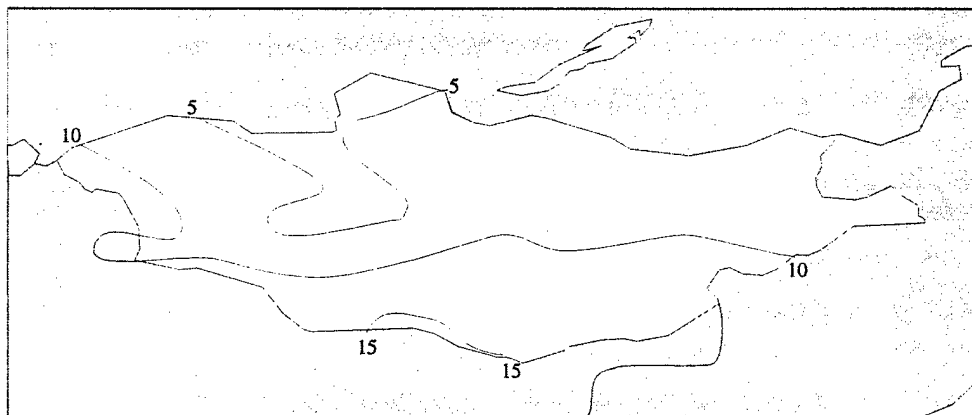


Figure 5-19. April Mean Maximum Temperatures (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

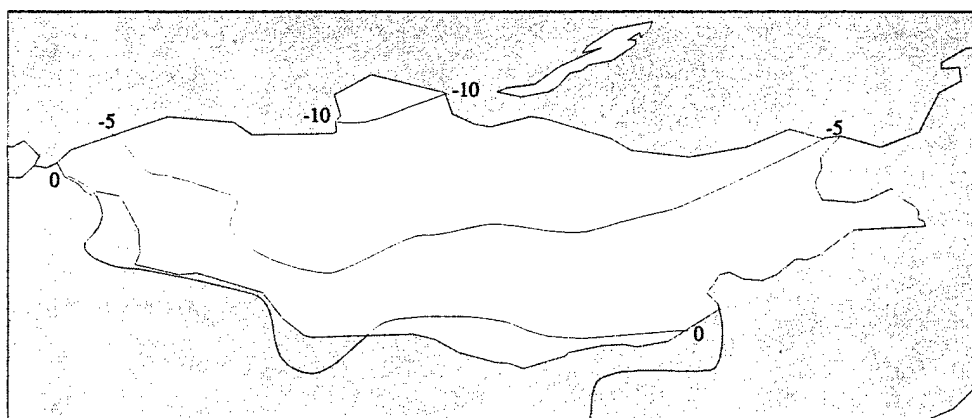


Figure 5-20. April Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

Hazards.

Aircraft Icing. Icing is mainly restricted to altocumulus and altostratus layers found in the migratory frontal systems that pass through the region from the distant Atlantic Ocean moisture source. Low-level moisture is normally too scarce to allow any more than a trace of icing. Light-to-moderate rime icing occurs in the light but nearly continuous snowfall found over the Altai, Hentiyn, and Hangayn mountains.

Turbulence. Strong post-frontal northwesterly winds blow perpendicular to the southwest-northeast oriented Hentiyn Mountains and produce conditions conducive to mountain wave turbulence. With sufficient moisture available, altocumulus standing lenticular (ACSL) clouds will form on the lee side of the ridge line; however, since the air is usually too dry, ACSL will not normally be visible. Moderate-to-severe turbulence will still exist, up to 45 to 62 miles (75-100 km) downstream and up to an altitude of 45,000 to 95,000 feet (15 to 30 km). Additionally, strong winds funneled through the valleys of the Hangayn and Altai mountains produce moderate-to-occasionally severe turbulence.

Usually on the second day after the frontal passage, the mountain wave breaks down. The winds shift from a northerly direction to an easterly or southeasterly direction. Once the perpendicular component decreases, the mountain wave and the resulting turbulence dissipates. The peak time for mountain wave occurrence is from late winter into spring. This ties in with the weakening of the Siberian high, which opens the storm track into Mongolia.

Duststorms/Sandstorms. Even though duststorms and sandstorms can occur anytime during the year, the increased number of frontal passages make springtime the primary season for this phenomenon. The two primary factors required for duststorms/sandstorms are strong solar heating and mean wind speeds greater than 15 knots. The arid soil, along with sparse vegetation, make the Gobi Desert a prime area for this phenomenon. During the 30 or more sandstorms that occur in the region each year, both dust and sand are lifted as high as 13,000 feet (4,000 meters) AGL. Visibility is restricted to near zero for usually 2 hours, but conditions can persist for as long as 24 hours.

Blowing dust and sand are the most common and are the most serious hazards to operations in northwest China. Dust is a finer, smaller atmospheric particle that is nearly always present in the deserts. Sand is a larger, more coarse particle that requires greater wind speeds to be lifted—usually less than 6 feet above the surface—and transported. Additionally, stronger winds and longer trajectories will cause sand and dust particles to be lifted higher. Aircraft downrush raises dust and sand from the desert floor, reducing visibility in the immediate vicinity of the aircraft. Also, dust and sand enter engine intakes and cause damage. During severe sandstorm conditions, ablation of windscreens and other aircraft parts can occur. Persistent dust conditions also cause problems with dry skin, sore throat, and cracked lips. Dust also contributes to radio signal degradation. A heavy electrostatic discharge may result from the impact of windblown particles striking an object. The surprisingly high-voltage sparking associated with these electrostatic discharges can pose a hazard to personnel and equipment.

Trafficability. Mongolia is a country of high elevations with three major topographic areas. There areas include the following: (1) massive, forested, high mountains to the center, north, and west, (2) large basins between the mountains, and (3) an upland plateau across the south and east that consists of desert, semidesert, and upland steppe.

The mountains of the west are the highest and most rugged. The northern and central mountains have characteristically long, gentle slopes and crests covered with large, alpine pastures. The higher parts are very rough and rugged. With a few exceptions, movement in these mountains is unsuitable at all times because of the steep, rugged terrain. The exceptions are the gently sloping pastures. Here the soils are shallow to moderately deep and are mainly coarse to medium-grained or a mixture of both. Movement in these areas is fair when the soils are dry and not snow covered. When wet and not frozen, conditions are poor to fair because of soft and slippery surfaces.

In the intermontane basin areas, slopes vary. They are mostly gentle to rolling slopes. Soils are

predominantly deep and are a mix of coarse and fine-grained. When dry, movement conditions are fair to poor. When wet, the soils are soft and cause movement conditions to be unsuitable.

Most of the southern part of the country is rolling desert plain. This area is part of the great Gobi which is mainly stony desert. Some areas of dunes and sand plains occur in the west and south of this region and variously sized salt flats are scattered throughout. Soils are mainly coarse-grained. Fine-grained soils occur in salt flats. Movement conditions are fair to good most of the time except in sand dunes and places where the plain is broken by heavily dissected ranges.

The east part of Mongolia is rolling to hilly steppe plains that become flatter in the extreme east. Soils are moderately deep to deep and range from coarse to fine-grained. Movement conditions are fair to good except during the spring thaw. During this time, movement conditions vary from poor to unsuitable. Conditions depend on soil type; the best conditions are found in the areas with the coarse-grained soils.

General Weather. Summer is classified as the rainy season of Mongolia. Most Mongolian stations record up to 75 percent of their annual precipitation totals during summer. In some cases, the mean number of rainfall days nearly triples from spring to summer months. Additionally, most thunderstorm activity occurs during summer.

By June, the summer circulation patterns are firmly in place. The Azores high, now at its northernmost position (37° N, 37° W), imports the greatest amount of moisture to the area at any time of the year. The westerlies aloft bring migratory systems from the Atlantic, across Europe and central Asia, to Mongolia. By the time these systems reach Mongolia, they normally contain only mid- and upper-level moisture. Most of the low-level moisture is deposited as rainfall in the mountains of Europe and central Asia. However, there is usually enough moisture left to create convection over the highest peaks of the Altai and Hangayn mountains of western Mongolia. As the sun approaches its northernmost position, the large Asian landmass heats dramatically, forming a large-scale warm core low-pressure system. This thermal low is normally centered over Pakistan or northwestern India and acts as an anchor at the extreme western end of the monsoon trough. The resulting weak low-level circulation brings moisture from the western Pacific into eastern Mongolia.

At the same time, the sun heats the Tibetan Massif, which warms the upper-level air and creates an upper-tropospheric subtropical ridge, or the Tibetan 200-mb anticyclone. The enormous amount of latent heat, released during the southwest monsoon rains, reinforces the ridge. By late June, the anticyclone is firmly entrenched over southern Tibet, forcing the subtropical jet to its northernmost position, southern Mongolia. The mean position of the subtropical jet enters western Mongolia along the southern edge of the Altai Mountains and continues eastward along the northern periphery of the Gobi Desert before exiting Mongolia just east of the city of Bajndelger. This mean position places the arid Gobi in the confluent southeastern quadrant of the jet maximum and places north and northeastern Mongolia in the diffluent northeast quadrant of the subtropical jet. The resultant upper-level dynamics in the diffluent northeastern quadrant enhance thunderstorm development, and conversely, the confluence aloft in the southeastern quadrant tends to inhibit thunderstorm development. The section of Mongolia in the northeastern quadrant of the subtropical jet records the greatest number of rain and thunderstorm days and the greatest amount of precipitation in the country. Orographically assisted convection in this region continues to develop and is enhanced as a result of the diffluence aloft.

Sky Cover. Summer is the cloudiest season in Mongolia. Cloud types are predominately cumuliform and convective in nature. Cumulus normally begins to form by late morning and continues to develop in response to the strong afternoon surface heating. By late afternoon, the sky condition is normally either broken or overcast. Diurnally, late afternoon is the time of greatest occurrence of ceilings below 3,000 feet. Some locations report these low ceilings up to 50 percent of the time at certain hours of the day.

However, soon after sunset, the afternoon cumulus quickly dissipates because of the loss of solar heating. Throughout the evening only altocumulus and cirrostratus debris from afternoon thunderstorms remain. Cumulonimbus clouds normally form over the highest mountains and remain for several hours past sunset. Debris from mountain thunderstorms remain through the night and occasionally into the following morning. Figure 5-21 shows the frequency of ceilings below 3,000 feet for selected locations at different times of day.

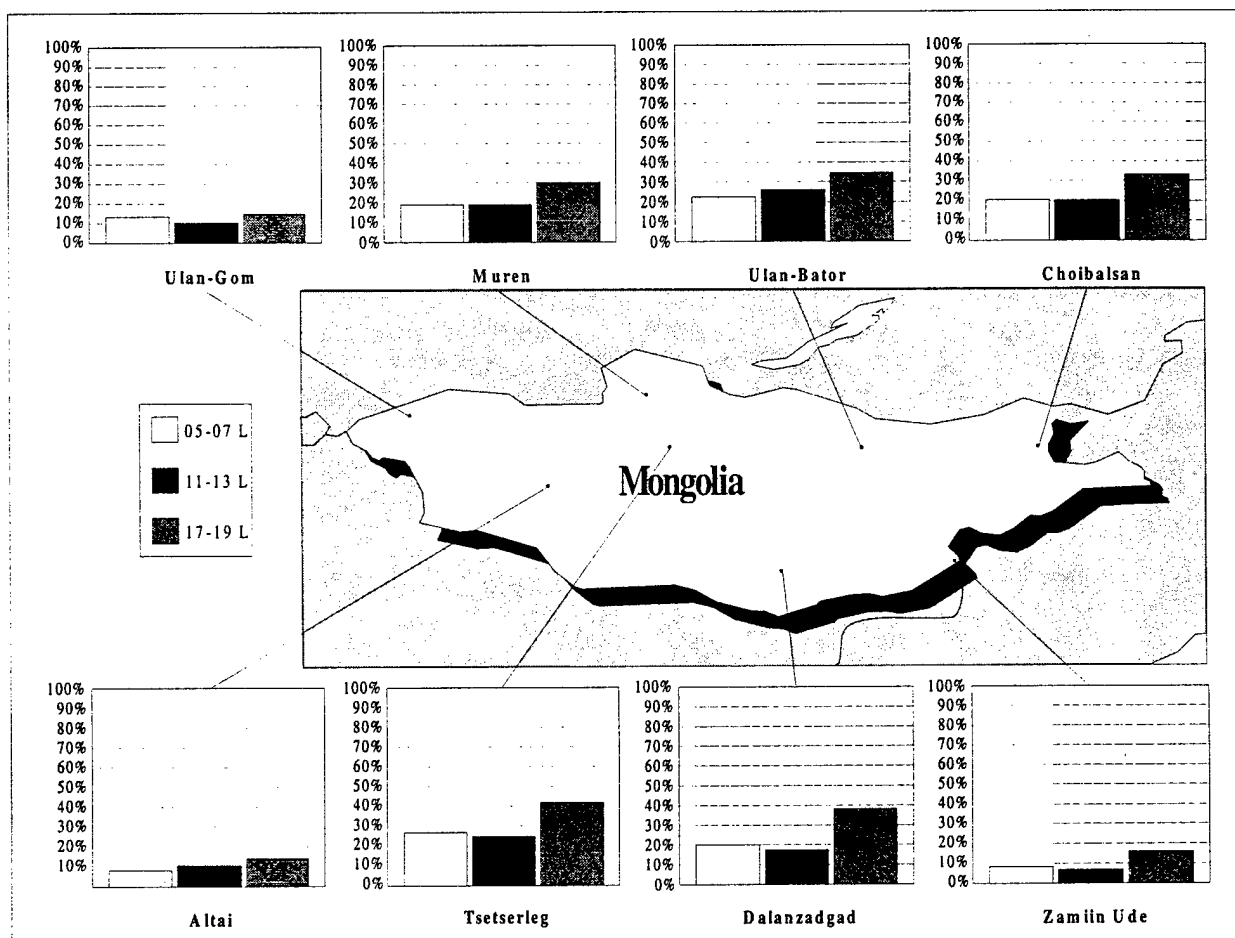


Figure 5-21. July Ceilings below 3,000 Feet. This figure depicts the changes in diurnal frequency of low ceilings at selected locations across Mongolia.

Visibility. Visibility for most Mongolian stations during summer is normally excellent. Visibility remains typically unrestricted during rainshowers and thunderstorms and only drops for brief periods during short-lived heavy showers. Most Mongolian stations report visibility reduced to below 4,800 meters less than 5 percent of the time. Few stations report restricted visibility greater than 5 percent, and only then for brief periods in the early morning hours (see Figure 5-22). Only two stations report restricted visibility greater than 10 percent of the time, Ulan-Bator and Hatgal.

Ulan-Bator averages visibility less than 4,800 meters 14.7 percent of the time during the early morning hours. For most of the year, Ulan-Bator reports poor visibility because the city is located in a valley and is surrounded by mountains that tend to trap fog, haze, and pollutants. In actuality, even though Ulan-Bator has the highest frequency of restricted visibility of any city in Mongolia, the summer is

the best season for visibility in the capital. Fog, the primary restriction to Ulan-bator's visibility, occurs much less commonly in the summer than during any other season. Like Ulan-Bator, fog is also the main reason for the reduced visibility at Hatgal, but the situation is somewhat different.

Hatgal averages visibility reduced to less than 4,800 meters up to 14 percent of the time. Like Ulan-Bator, Hatgal is also in a valley surrounded by mountains, but the visibility is only reduced for brief periods during the early morning hours. However, summer is the worst season for visibility at Hatgal. Hatgal reports the highest frequency of poor visibility at any time of year during the summer months due to increased moisture availability. During the other 9 months of the year, Hatgal only averages 1 fog day a month. During the 3 months of summer, the average increases to 5 days per month.

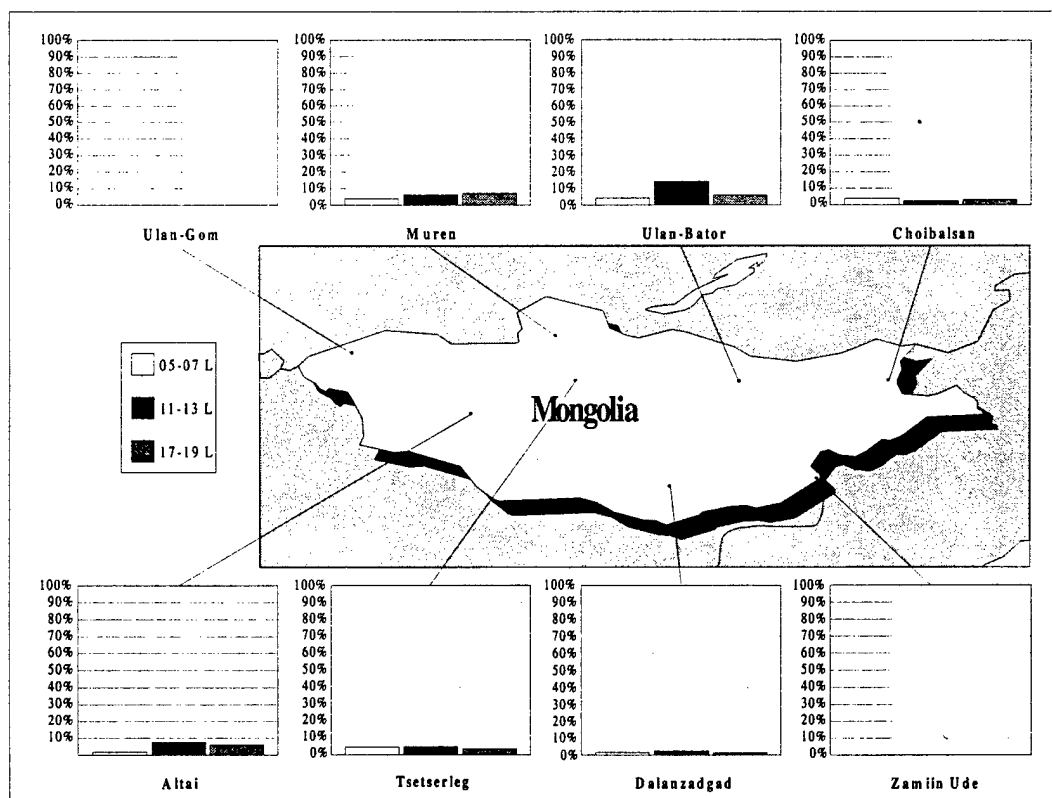


Figure 5-22. July Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. During summer, terrain continues to influence wind direction and speed. There is more variability in wind directions because of the influence of the Asiatic low. These effects are depicted in Figures 5-23 and 5-24. Even so, most stations still show a predominately westerly or northwesterly component. Across the eastern plateau and the Gobi Desert, an easterly or southeasterly wind usually signals the onset of precipitation. This seasonal shift in wind direction is responsible for the higher amounts of precipitation that occur during the summer in the east.

Wind speeds are generally highest in the afternoon. There is usually a lull in the wind speeds in the evening and again just before sunrise. As the morning progresses, wind speeds slowly increase until the inversion breaks in late morning. After the sun has been up for a few hours, the ground warms the lowest layer of the atmosphere, and turbulent mixing breaks the inversion. This allows the higher winds trapped above the inversion to mix to the surface. After sunset, as the ground quickly cools, the inversion reforms in the lowest 1,600-2,600 feet (500-800 meters) above the surface. A low-level jet forms just above the inversion layer. Wind speeds found in this low-level jet are generally in the 25- to 35- knot range.

Diurnal mountain and valley breezes are common in the broad north-central intermontane valleys and northwest of Mongolia. Downslope mountain breezes flow from the Hangayn and the Altai Mountains at night as the slopes rapidly cool. To a lesser extent, the same phenomena occurs in the Gobi Altai and Hentiyn mountains, affecting nearby locations in the Gobi Desert and on the eastern plateau. The windflow reverses as the mountain slopes warm during the day and produce an upslope valley breeze. This upslope condition aids in cumulus cloud formation along mountain peaks. Both mountain and valley

breeze effects are accentuated at locations hemmed in by surrounding mountains.

Lake and land breezes, also diurnal in nature, occur most commonly in the Great Lakes region in the northwest. Weak land breezes occur at night as the land cools and the pressure over land rises. Higher pressure found over land flows towards lower pressure found over the nearby lakes. Land breezes are strongest just before midnight, coinciding with the time of diurnal pressure maximum. They last until just before sunrise when the diurnal pressure curve reaches its secondary minimum. Land breezes extend approximately 1.2 to 1.8 miles (2-3 km above the surface and are normally only 5-8 knots in strength.

On the other hand, lake breezes are typically twice as strong. Lake breezes are strongest in the late afternoon, near the time of diurnal pressure minimum. This also coincides with the time of maximum heating, thereby strengthening the effects of the lake breeze. Lake breezes are nearly twice as strong as land breezes and only extend to 1-1.5 km AGL. Lake breezes are usually 10-15 knots, but they occasionally reach as high as 25 knots in strength. Lake breezes have a profound effect on the windflow at stations near lakes; they also influence the temperatures at these stations. Additionally lake breezes are responsible for localized convection ahead of the "lake-breeze front." These effects are particularly enhanced when combined with upslope valley breezes.

The highest wind speeds ever recorded in Mongolia are found in the northeastern quadrant of the nation. Most sites in this region have recorded maximum summertime wind speeds in excess of 60 knots; Matad holds the record with 70 knots. These high wind speeds are attributed to the strong thunderstorms found in this area. Also, the flat, unobstructed terrain of the eastern plateau offers little resistance to block these strong winds.

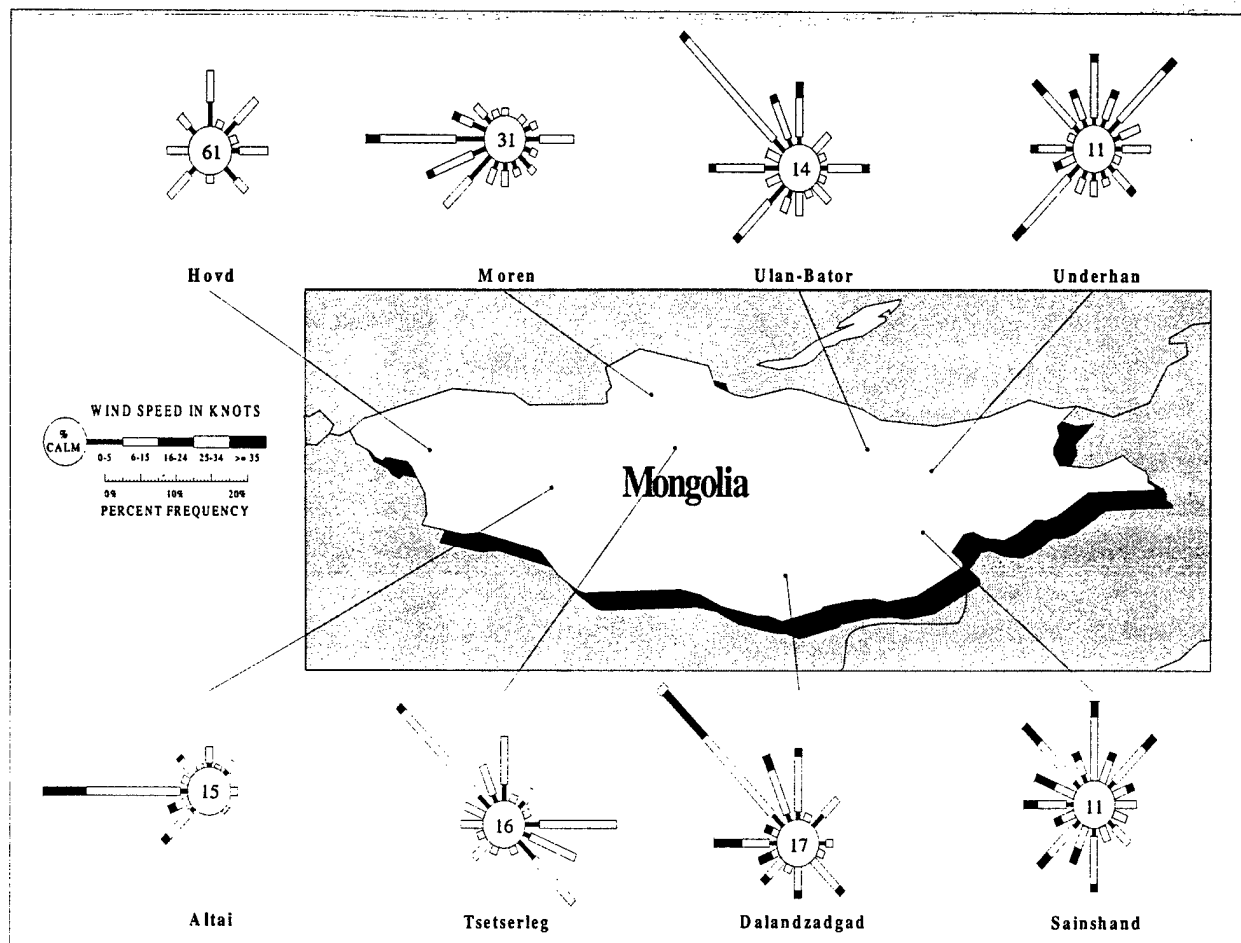


Figure 5-23. July 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on percentage frequency and location.

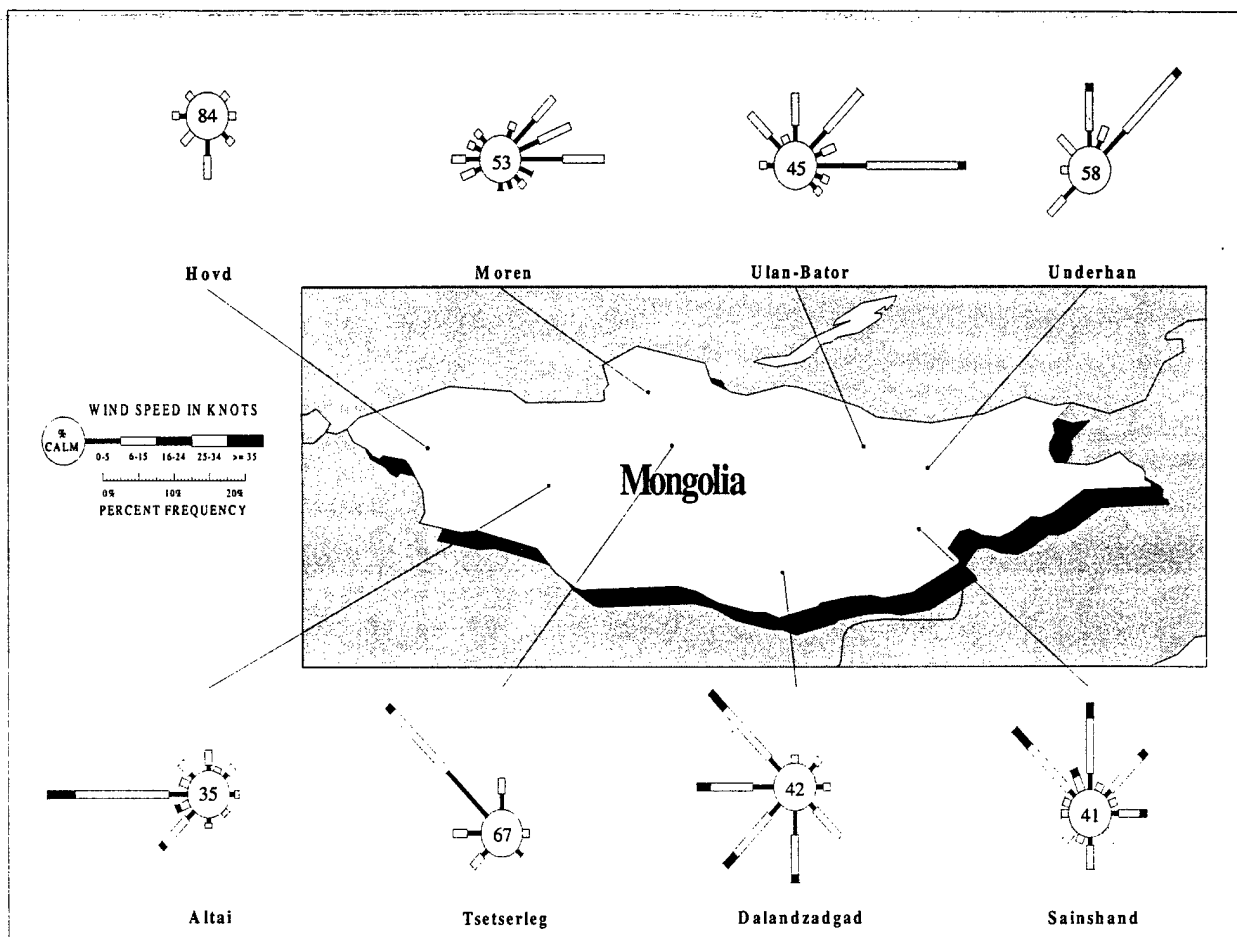


Figure 5-24. July 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on percentage frequency and location.

Upper-Air Winds. The polar jet is much weaker, and is located in south-central Siberia, just north of Lake Baykal. The subtropical jet is normally located at its northernmost position, around the northern periphery of the Tibetan anticyclone. The subtropical jet usually enters Mongolia in the west between the Altai Mountains and the extreme western Gobi Desert. The subtropical jet extends eastward, along the northern rim of the Gobi, before exiting northeast of Bajndelger.

The subtropical jet is strongest at the 200-mb level, where wind speeds are normally in the 30-60 knot range but reach speeds of up to 90 knots 5 percent of the time. Above 700 mb wind directions are predominately westerly, although, a considerable percentage occurs from the southwesterly or northwesterly direction. The strongest wind speeds are associated with the dominant wind direction. At 850 mb, wind directions and speeds are influenced by local and terrain effects. Figure 5-25 depicts wind roses from 850 to 300 mb for Ulan-Bator.

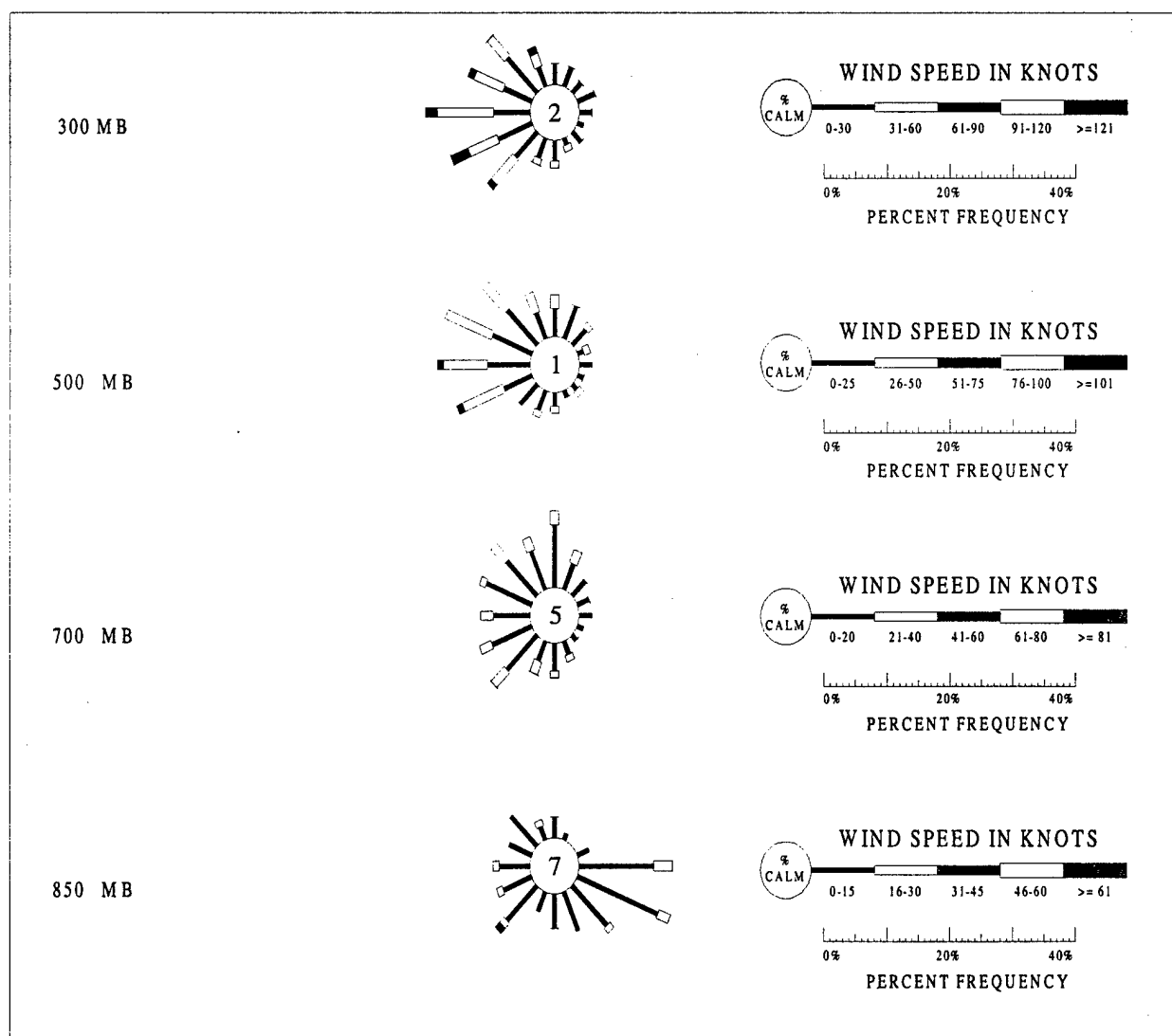


Figure 5-25. July Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Ulan-Bator. Each wind rose has a tailored legend.

Precipitation/Thunderstorms. Mongolia averages up to 90 percent of its annual precipitation during the 3 months of summer, and almost 100 percent of Mongolian thunderstorms occur during summer. Additionally, many stations record up to 75 percent of its annual rain days during summer. Since the Mongolian climate is temperate, a few sites located at the highest elevations of the Altai and Hangayn mountains even record 1 or 2 days with snowfall during the summer.

The Arctic Ocean is the primary low-level moisture source as cold, moist air from that source region moves across the flat terrain of central Siberia into northern Mongolia. The airflow around the Asiatic low brings hot, dry air into southern Mongolia. The subtropical jet enters southern Mongolia in June and migrates poleward in July. The migration is in response to the building 200-mb anticyclone in southern Tibet. As the subtropical jet migrates into Mongolia, a contrast is created between the hot, dry, continental tropical air mass to the south and the warm, moist continental polar air mass to the north. This is why thunderstorm activity occurs in this season.

In June, most of the precipitation falls across northern and northwestern Mongolia. The eastern plateau and the Gobi Desert are still comparatively dry. As the subtropical jet moves

poleward in July, the ridge axis moves across central Mongolia. This places the Hentiyn Mountains and the eastern section of the nation in the diffluent northeastern quadrant of the subtropical jet. Precipitation decreases across the west and increases dramatically in the east. This upper-level diffluence enhances thunderstorm development across Mongolia, especially in the northeastern section of the country. By August, as the subtropical jet quickly migrates equatorward, precipitation increases across the west and decreases in the east. Figures 5-26 and 5-27 show the mean precipitation amounts across Mongolia for July as well as the mean number of thunderstorm and rainfall days during July for selected stations across Mongolia.

For many of the Gobi oases, the only water available falls during brief summer downpours. Flash flooding briefly fills the many dry riverbeds that cross the Gobi. Most of this water is stored in subterranean aquifers that supply the oases during the remainder of the year. This is also the wettest time of the year for the fertile Orhon River valley. The brief rainy season is critical to agriculture in Mongolia because the only arable land in the nation is located in this region. By far, most of the nation's precipitation falls on the northern slopes of the mountains of Mongolia. In addition to the melting snow runoff these summer rains fill the streams that empty into the Great Lakes of the northwest.

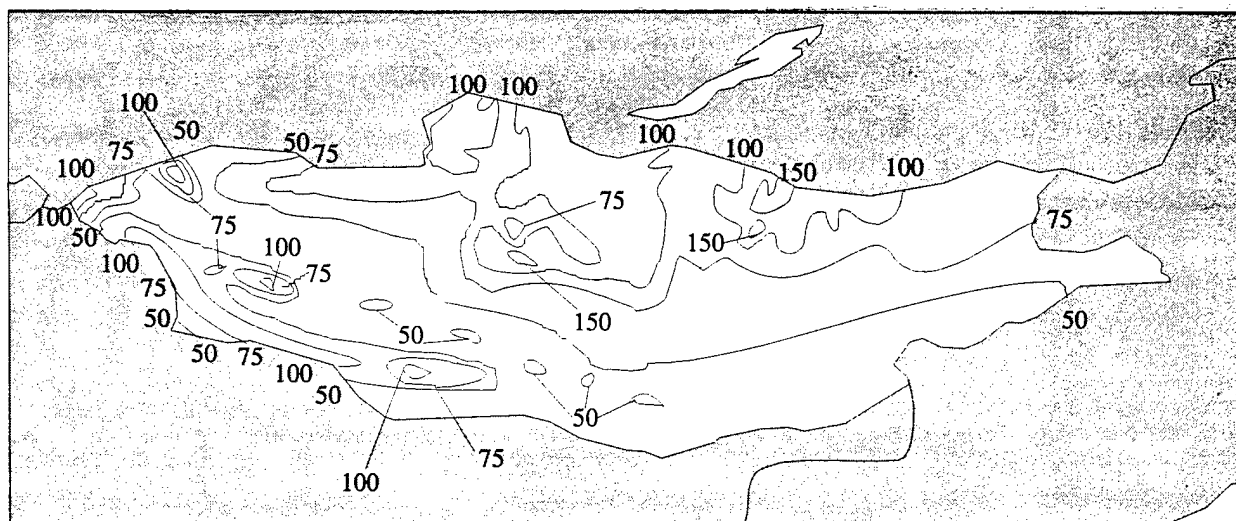


Figure 5-26. July Mean Precipitation (mm). The isopleths show the rainy season across Mongolia.

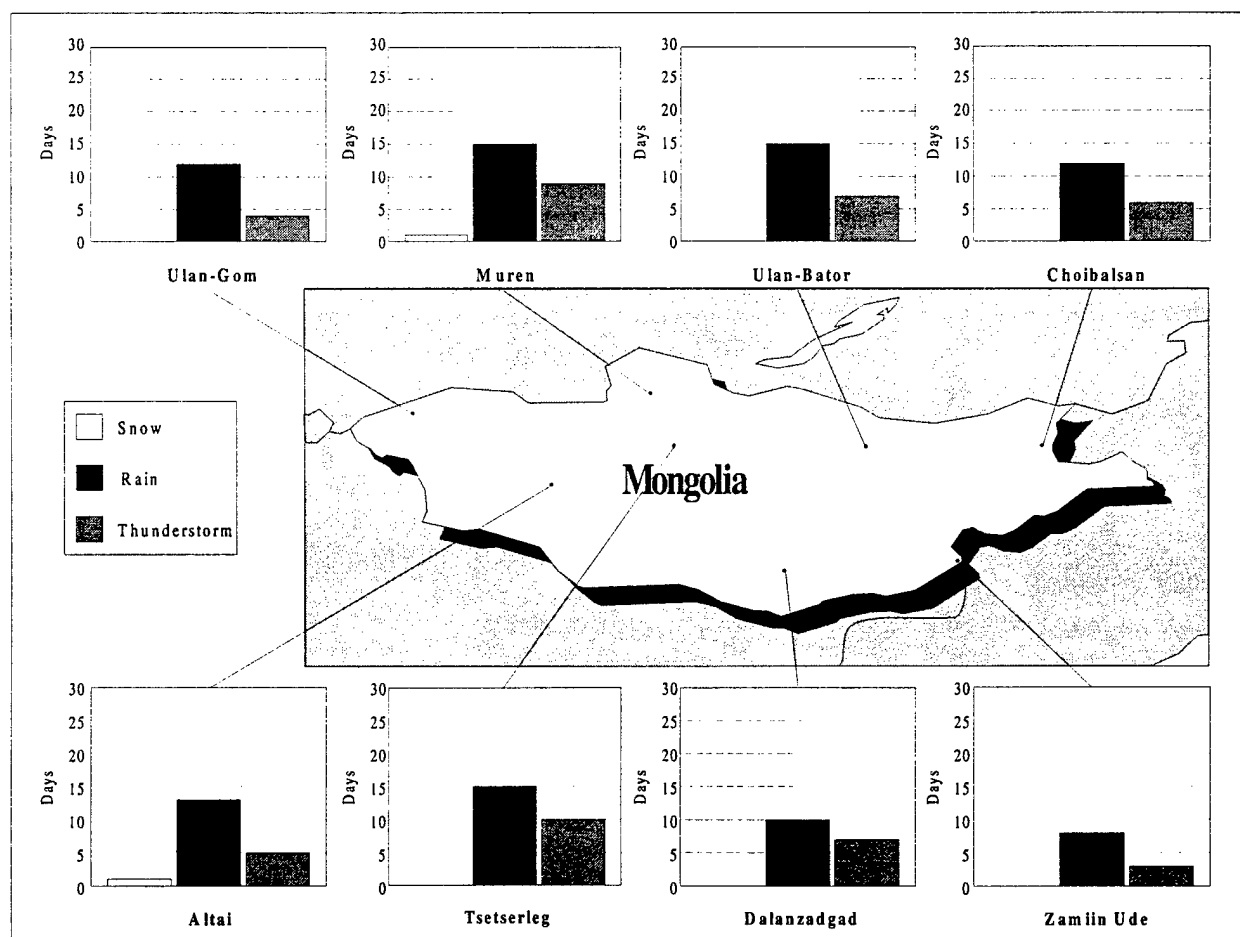


Figure 5-27. July Mean Snow, Rain, and Thunderstorm Days. The graphs show the mean number of days with rain and thunderstorms for selected locations across Mongolia.

Temperatures. The latitude and terrain of Mongolia keep the climate mild and temperate. The warmest mean maximum temperatures are found in the southern and eastern sections of the Gobi Desert and the eastern plateau. Most stations in this area have mean daily maximums exceeding 77°F (25°C). Sainshand and Zamiin Ude are the warmest with an average high temperature of 82°F (28°C). These regions also have the warmest mean daily minimum temperatures in Mongolia; most sites exceed 54°F (12°C). Choir, Dalanzadgad, and Zamiin Ude have the warmest mean daily minimum, a temperature of 57°F (14°C) (see Figure 5-28).

The coolest locations in Mongolia are found in the northern mountains. Many locations in this area have mean daily maximums under 68°F (20°C). Hatgal is the coldest with a mean daily maximum of only 63°F (17°C) during summer. The strong

lake breeze from Lake Hövsgöl brings cold, moist air to Hatgal. With a mean daily minimum of only 39°F (4°C), Hatgal also has the lowest mean daily minimum temperature. The lakes in the Great Lakes region moderate temperatures of nearby stations. Most mountainous locations have mean daily minimums under 50°F (10°C) (see Figure 5-29).

There is a remarkably large range between seasonal extreme minimum and maximum temperatures. Every Mongolian station has recorded summer temperatures below freezing, and all but the sites located in the highest elevations have recorded extreme maximums exceeding 95°F (35°C). Tsogt-Ovoo holds the record with an extreme maximum of 117°F (47°C). Several stations hold the record for extreme minimum temperature. Galut, Ulan-Bator, and Bayan Suma have all recorded an extreme minimum of 14°F (-10°C).

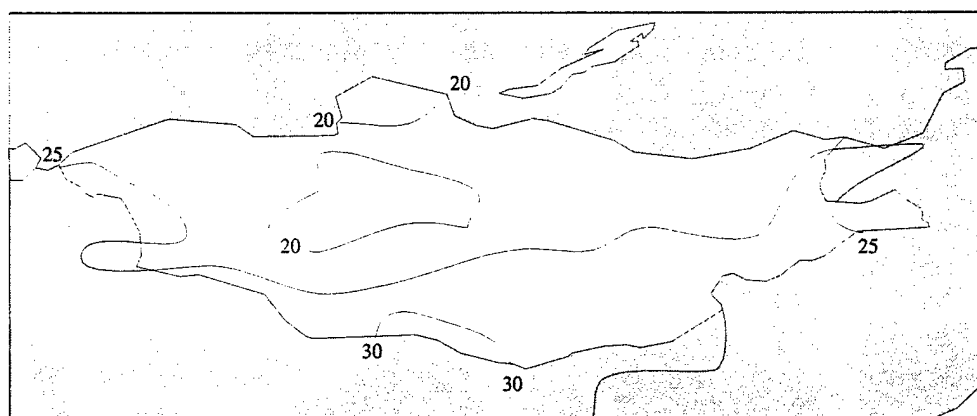


Figure 5-28. July Mean Maximum Temperatures in (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

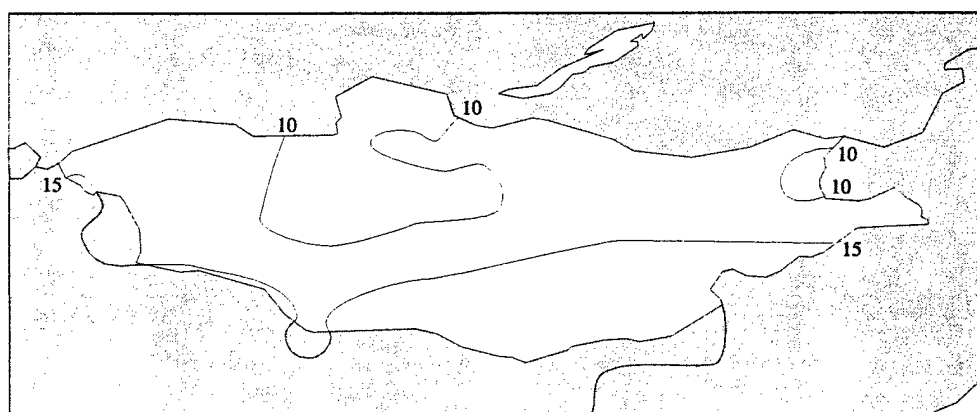


Figure 5-29. July Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

Hazards. The sparse vegetation and arid soil of the Gobi Desert make it extremely susceptible to flash floods. Most of the annual precipitation is recorded during brief, but heavy summer downpours. The dry riverbeds that cross the desert briefly fill with

rapidly flowing currents. However, even after the most extensive series of storms, the riverbeds once again dry up. Some of the water evaporates into the atmosphere, but most of it drains into underground aquifers.

Trafficability. Mongolia is a country of high elevations with three major topographic areas. There areas include the following: (1) massive, forested, high mountains to the center, north, and west, (2) large basins between the mountains, and (3) an upland plateau across the south and east that consists of desert, semidesert, and upland steppe.

The mountains of the west are the highest and most rugged. The northern and central mountains have characteristically long, gentle slopes and crests covered with large, alpine pastures. The higher parts are very rough and rugged. With a few exceptions, movement in these mountains is unsuitable at all times because of the steep, rugged terrain. The exceptions are the gently sloping pastures. Here the soils are shallow to moderately deep and are mainly coarse to medium-grained or a mixture of both. When soils are wet and not frozen, movement conditions are poor to fair because of soft and slippery surfaces.

In the intermontane basin areas, slopes vary. They are mostly gentle to rolling slopes. Soils are predominantly deep and are a mix of coarse and fine-grained. When wet, the soils are soft and cause movement conditions to be unsuitable.

Most of the southern part of the country is rolling desert plain. This area is part of the great Gobi, which is mainly stony desert. Some areas of dunes and sand plains occur in the western and southern portion of this region. Various sized salt flats are scattered throughout. Soils are mainly coarse-grained. Fine-grained soils occur in salt flats. Movement conditions are fair to good most of the time except in sand dunes and in locations where the plain is broken by heavily dissected ranges.

The east part of Mongolia is rolling to hilly steppe plains that become flatter in the extreme east. Soils are moderately deep to deep and range from coarse to fine-grained. Conditions depend on soil type. The best conditions are found in areas with coarse-grained soils.

General Weather. This short transition season is the most pleasant time of the year in Mongolia. By September, the summer rains have ended, and the days quickly cool. The change from the summer to the winter regime is abrupt and well-defined. By mid-September, the Tibetan 200-mb anticyclone is gone, and the subtropical jet moves from the Sino-Mongolian border to a position over north-central Tibet. The polar jet begins to reappear and strengthen over south-central Mongolia. As the sun approaches the autumnal equinox, the central Asian landmass quickly cools. By the middle of October, there is sufficient radiational cooling to form the

Siberian high. As the Azores high migrates south, the moisture available to Mongolia is greatly diminished. Additionally, the low-level moisture from the Arctic Ocean is also reduced because it freezes over by October. In October, the subtropical jet is situated across the southern Tibetan Plateau. The polar jet is well defined, just south of the border, in northern China. The arctic jet is faintly detectable over the Lake Baykal region. By the end of October, the Siberian high is firmly entrenched over western Mongolia, signalling the onset of winter.

Sky Cover. Fall marks a rapid decrease in total cloud coverage and frequency of ceilings at all levels. Total cloud coverage ranges from a maximum of 50-60 percent in the extreme northwest to a minimum of 20-30 percent across the Gobi Desert. The vast majority of cloudiness across Mongolia is found at the middle and upper levels. These clouds originate from the distant oceanic moisture sources and travel to Mongolia via the prevalent west-northwesterly flow. Low ceilings dramatically decrease from the cloudy days of summer. Stations located in valleys or near

sizable moisture sources average ceilings below 3,000 feet approximately 10 percent of the time. Figure 5-30 shows the frequency of ceiling below 3,000 feet at selected locations across Mongolia.

Cloud types reflect the transition of the seasons. Cumuliform clouds predominate until mid to late September when stratiform clouds become the norm. Stratus or stratocumulus is commonly found near lakes, rivers, and the northern slopes of mountains. Mid- and high-level clouds usually accompany transient minor short waves.

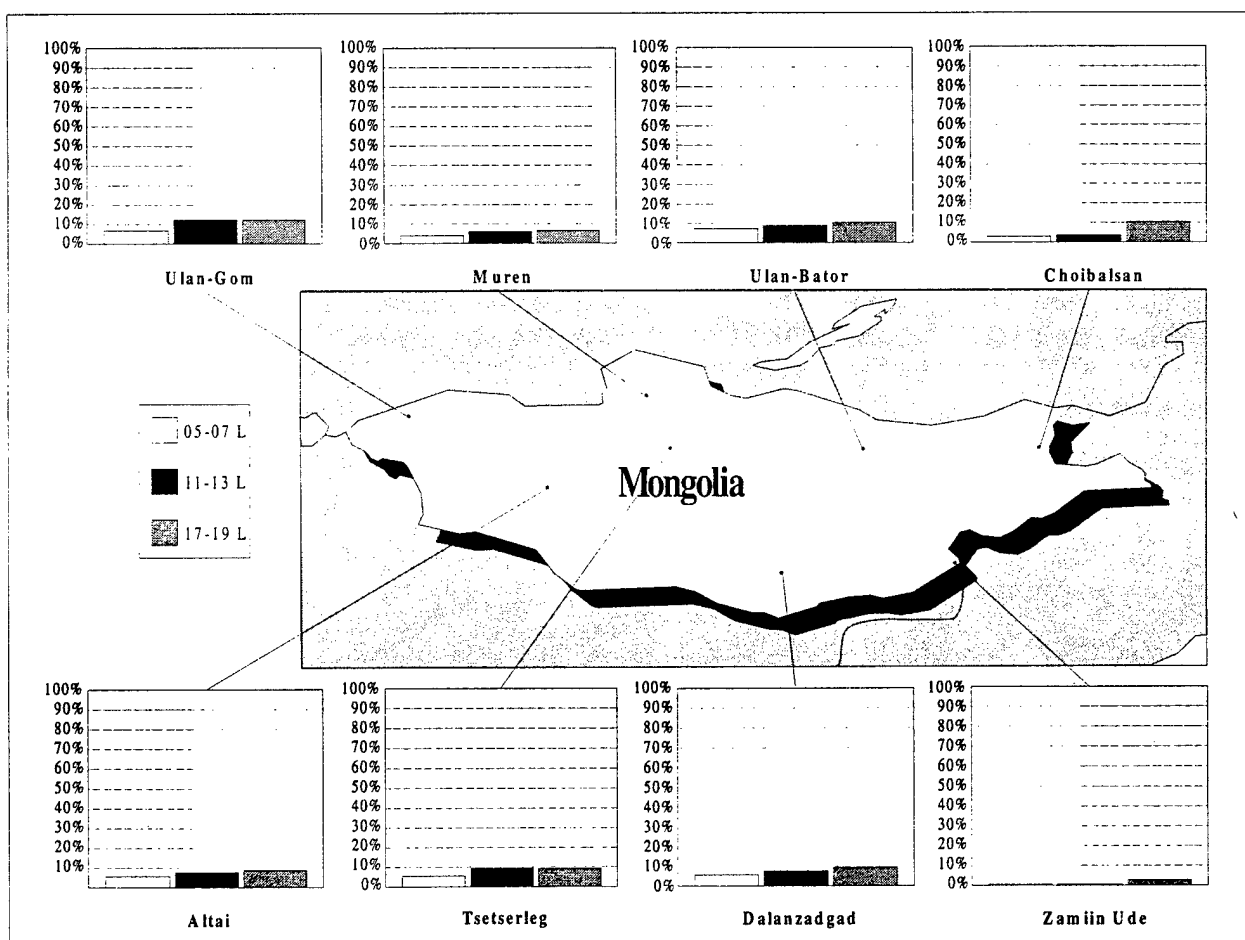


Figure 5-30. October Ceilings below 3,000 Feet. This figure depicts the changes in diurnal frequency of low ceilings at selected locations across Mongolia.

Visibility. Visibility across Mongolia is the best of any season. Every station in Mongolia, with the exception of Ulan-Bator records visibility below 4,800 meters less than 5 percent of the time (see Figure 5-31). The frequency of reduced visibility at Ulan-Bator shows a gradual increase from a summer minimum to a winter maximum. The percentage of time visibility at Ulan-Bator is below 4,800 meters increases from 27.5 percent in September to 37.4 percent in October. This city is particularly susceptible to trapped poor quality air (smog) because of the surrounding terrain. By October, the Siberian air mass dominates the region and creates a strong, capping inversion. As the temperature falls, the populace burns more hydrocarbons. Smoke is trapped under the inversion, which further reduces visibility.

The improvement to visibility near lakes, such as at Hatgal, can be attributed to a weaker lake breeze effect. In the fall, the water temperature of the lakes is at an annual maximum; however, the land surface temperature quickly decreases. As a result, lower pressure is found over the water, and higher pressure is found over land. These dynamics reduce the lake breeze, and enhance the land breeze effect. This dramatically improves the visibility at stations located near lakes. During the 1 to 4 days a month of snowfall at higher elevations, visibility is briefly restricted. In the Gobi Desert, visibility is restricted during the 5-10 days of blowing dust that occur in the fall. During these duststorms, visibility is generally restricted to less than 9,000 meters, but rarely and only briefly below 4,800 meters.

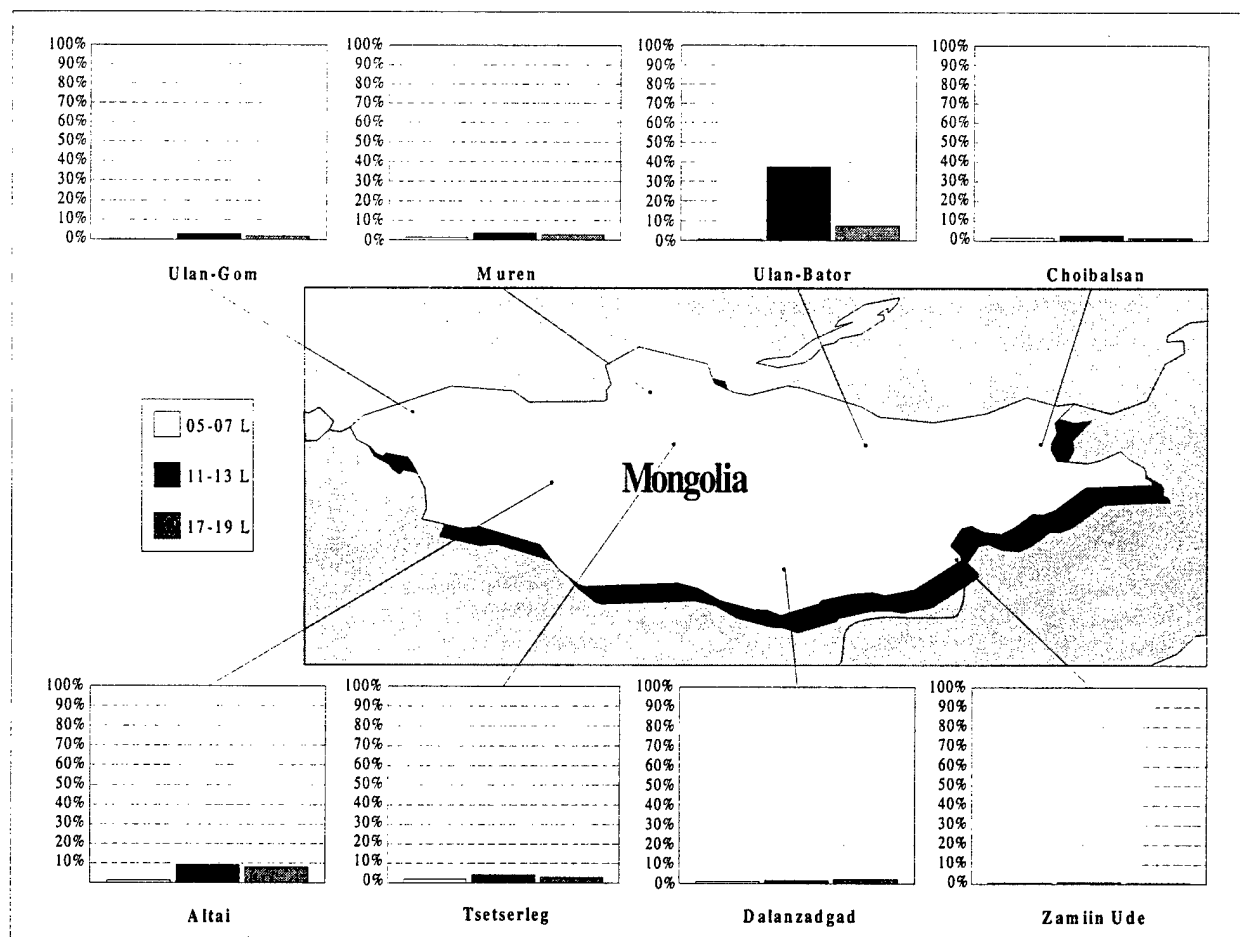


Figure 5-31. October Visibility below 4,800 Meters. The graphs show a breakdown of visibility less than 4,800 meters based on location and diurnal influences.

Surface Winds. In fall, winds more closely resemble those of winter. There is generally less variability in wind direction than during summer. The percentage of time that calm winds occur increases. Terrain and local effects have the most dominant influence now. By the time the Siberian high is firmly entrenched in late October, funneling is once again endemic to valley locations. At locations near lakes, the land breeze is at its annual maximum. The land breeze, which is most noticeable at night, is enhanced because the water temperature of the lakes is at an annual maximum. Only on the warmest days of fall does the land temperature get warm enough to create a lake breeze. When the lake breeze does occur, it is weaker, later, and shorter. Additionally, the distance from the lake that the breeze is felt is much smaller.

There is also an overall decrease in extreme

maximum wind speeds for this season.* For most locations, extreme wind speeds for fall are lower than any other season. Most locations have never recorded wind speeds in excess of 50 knots, and many have never exceeded 40 knots at this time of year. The most notable exceptions can be attributed to either strong föehn winds, strong frontal passages, or late summer thunderstorm downbursts. The highest of these was 70 knots, recorded at Hatgal. Since this was recorded in October, it was probably due to a frontal passage. Frontal passages in Mongolia during fall are rare, but the main storm track is just to the north, in the Lake Baykal region. This extreme wind speed was undoubtedly recorded during an exceptionally strong frontal passage. Ulgi, surrounded on all sides by the western Altai Mountains, also recorded 68 knots. The speed was most likely due to a föehn wind. Figures 5-32 and 5-33 depict 06Z and 18Z wind roses for eight selected stations across Mongolia.

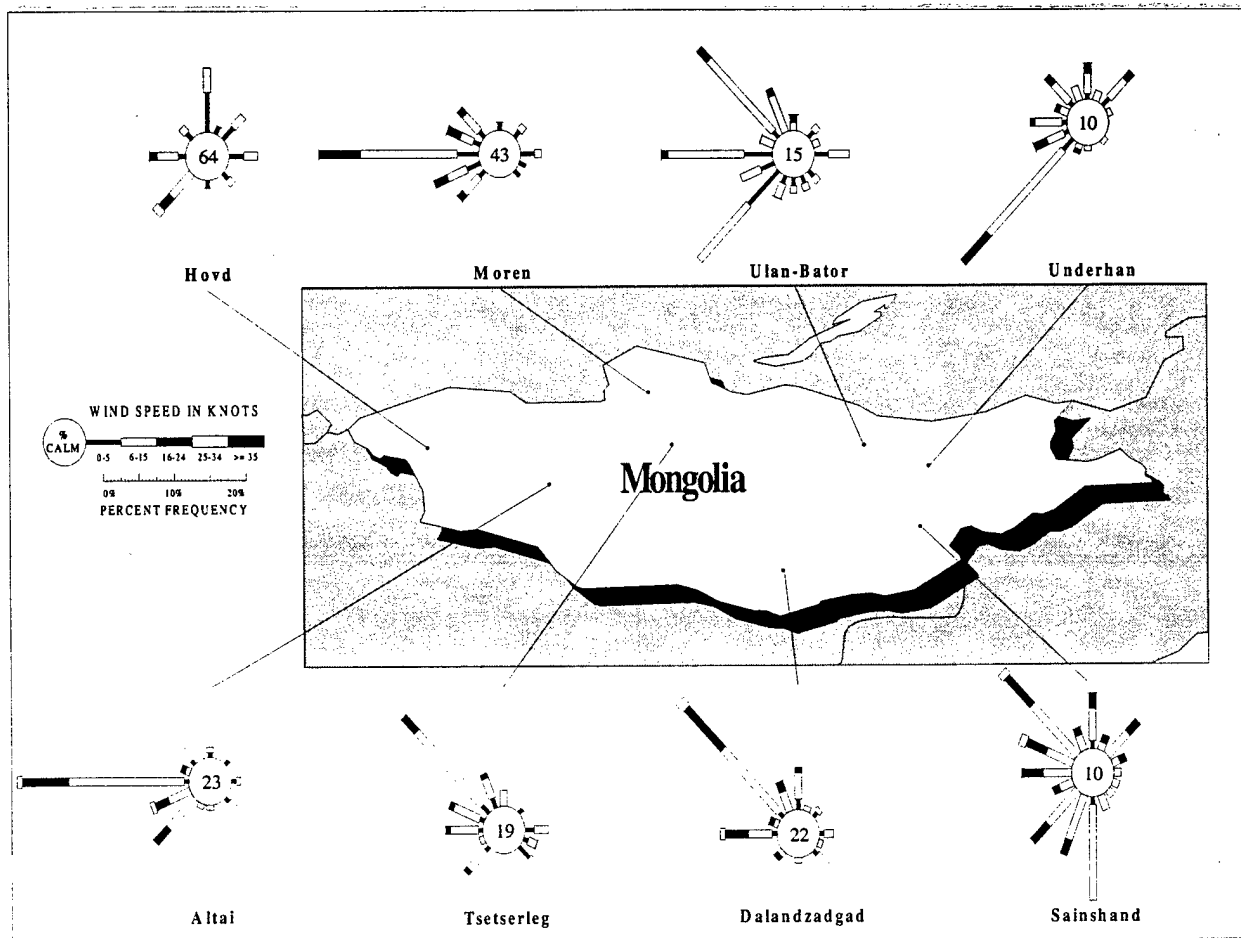


Figure 5-32. October 06Z Surface Wind Roses. The figure shows the prevailing midafternoon wind direction and range of speeds based on percentage frequency and location.

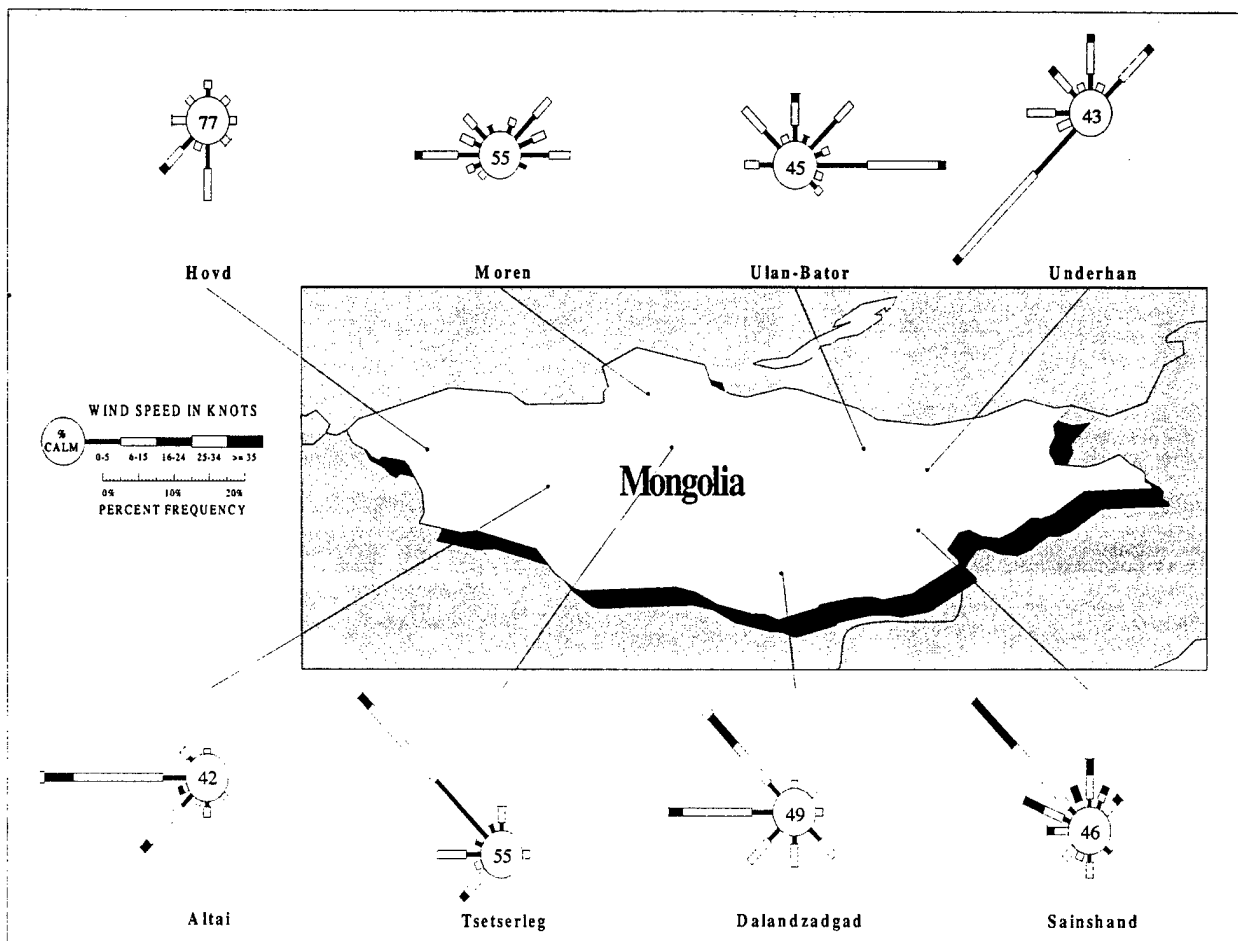


Figure 5-33. October 18Z Surface Wind Roses. The figure shows the prevailing predawn wind direction and range of speeds based on percentage frequency and location.

Upper-Air Winds. Westerlies continue to dominate the winds above 700 mb over Mongolia in fall. Wind speeds are generally higher across the south than in the north of Mongolia. In September, the polar jet approximately parallels the 46° N latitude and is best represented at the 200-mb level. Mean wind speeds in the polar jet are 50-60 knots. In October, the polar jet shifts south to approximately the 42° N latitude along the Sino-Mongolian border. Mean wind speeds in the polar jet increase to 60-75 knots, but the main jet core shifts eastward to a position just south of the Gobi Desert (see Figure 5-34). As the main polar jet shifts south, the mean wind speeds across Mongolia decrease to 40-50 knots. The arctic

jet is weakly represented between 200 and 300 mb. Located north of Lake Baykal, wind speeds in this jet occasionally reach 50 knots, but the arctic jet is not yet a major factor in Mongolia. In late October, as the Siberian high establishes itself, exceptionally strong arctic outbreaks strengthen and shift the arctic jet to northern Mongolia.

Winds at 850 mb and below are mainly influenced by the developing Siberian high and to a lesser extent by terrain and by local effects. The Siberian high is a shallow phenomenon barely extending to 850 mb and represented as a ridge above 700 mb.

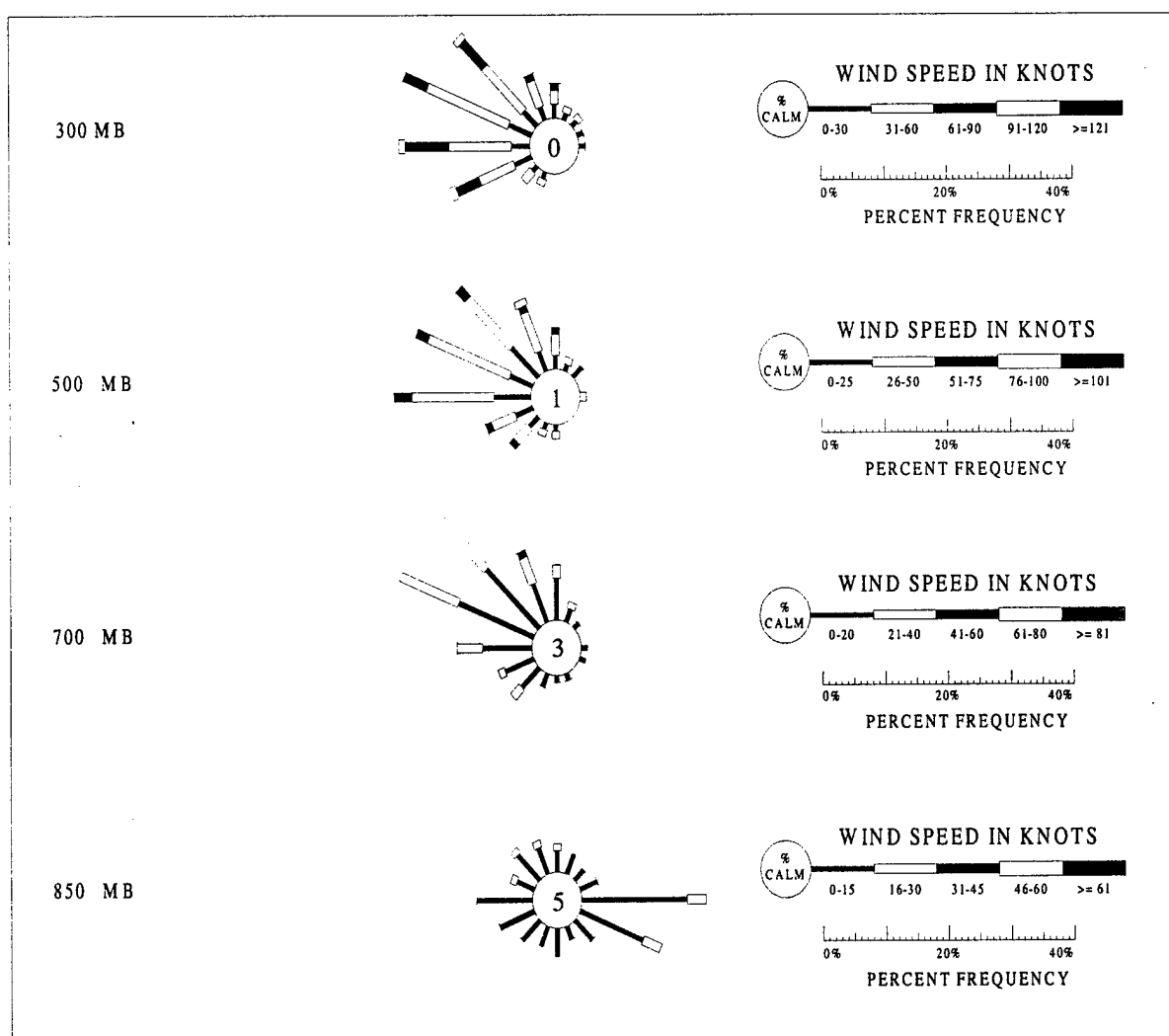


Figure 5-34. October Upper-Air Wind Roses. The upper-air wind roses depict wind speeds and directions for standard pressure surfaces between 850 and 300 mb at Ulan-Bator.

Precipitation. Fall is an abrupt and distinct season of transition between the warm rainshowers of summer, and the cold snows of winter. As the influence of the Siberian high increases, the amount of available moisture for precipitation decreases. Precipitation amounts across Mongolia in September closely resemble those of the end of summer, but October precipitation amounts look more like those found in winter. The highest precipitation totals, mostly in the form of snowfall, are found along the northern slopes of the Hentiyn Mountains. This small area is the only part of Mongolia that records between 25 and 50 mm of precipitable water. The majority of the country records less than 5 mm. Figure 5-35 depicts mean precipitation totals for Mongolia in October.

The stations with the highest number of rain days in September are found in the northeastern quadrant of Mongolia. Most of these rain days are holdovers from the summer season and happen before the transition occurs. Locations with

the most snow days in September are found in the extreme north and at the highest elevations of the Altai and Hangayn mountains. Even stations in the Gobi Desert average at least one snow day in September. One method of defining when the transition to winter is complete is noting when a station records more snow days than rain days.

Every Mongolian station records more rain days than snow days in September, but the situation reverses in October. Figure 5-36 shows the mean number of rain and snow days in October for selected locations across Mongolia. The number of rain days dwindles to 1 or 2 at all locations, but the number of snow days increases to 6 or 7 at some locales. The highest concentration of snow days in October is found in the mountains of the north and west. Upslope northwesterly winds from the developing Siberian high are responsible for snowfalls on the windward slopes of the mountains.

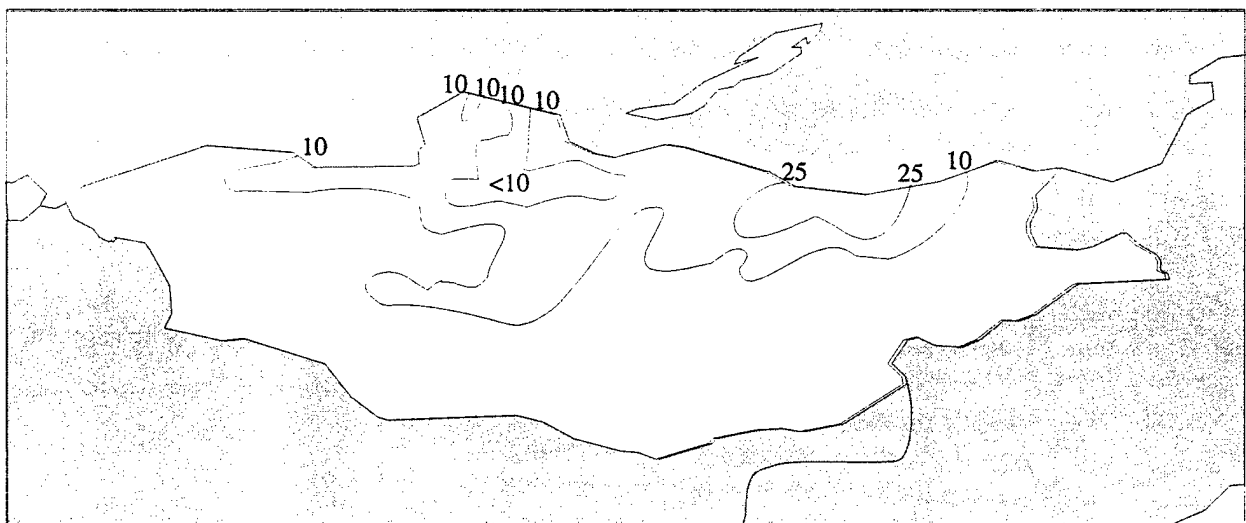


Figure 5-35. October Mean Precipitation (mm). The isopleths show the mean precipitation amounts for this transition season across Mongolia.

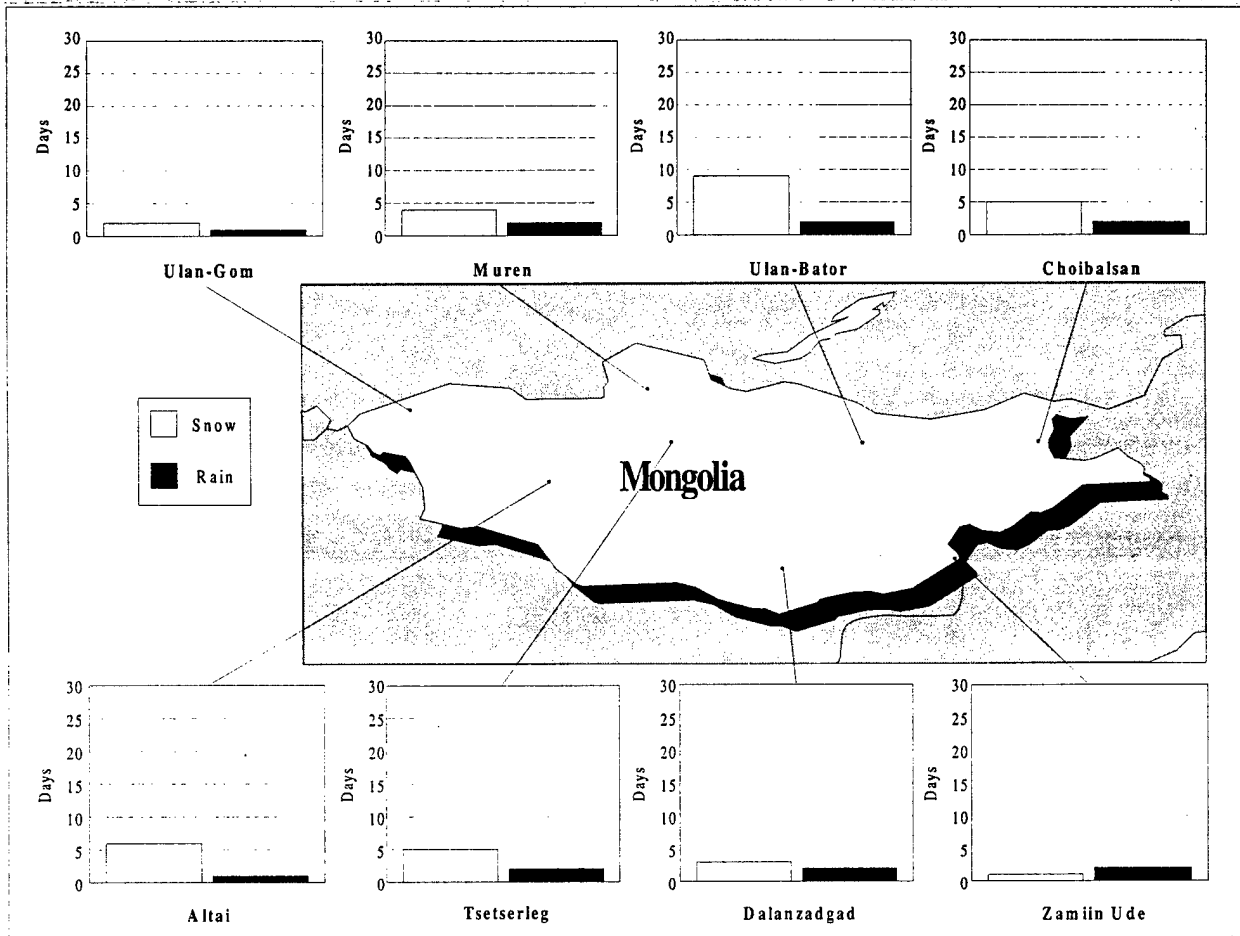


Figure 5-36. October Mean Snow and Rain Days. The graphs show the mean number of days with rain and snow for selected locations across Mongolia.

Temperatures. October temperatures in Mongolia mark the transition of the seasons. At the beginning of September, the sun only rises to a height of approximately 45 degrees above the southern horizon. The amount of solar radiation rapidly decreases with the onset of fall. This causes a corresponding drop in mean temperatures. The dry, stable Siberian air mass creates a large diurnal temperature range, averaging between 22 and 27 Fahrenheit (12 to 15 Celsius) degrees over Mongolia. In October, every Mongolian station has a mean daily minimum below freezing and a mean daily maximum well-above freezing. By late October, even the warmest stations of the Gobi Desert struggle to rise above freezing temperatures (see Figures 5-37 and 5-38).

The highest extreme maximum temperatures for October are found in the Gobi Desert and the southeastern quadrant of Mongolia. Most stations in this area have recorded extreme maximums between 77° and 86°F (25° and 30°C). Stations located in the north and in the highest mountain locations have recorded the lowest extreme maximums. Many of these sites have not exceeded 68°F (20°C). These sites have also recorded the coldest extreme minimum temperatures for Mongolia in October. Many of these sites have recorded extreme minimums in the -22° to -31°F (-30° to -35°C) range. Every station in the Gobi Desert has recorded an extreme minimum below 5°F (-15°C).

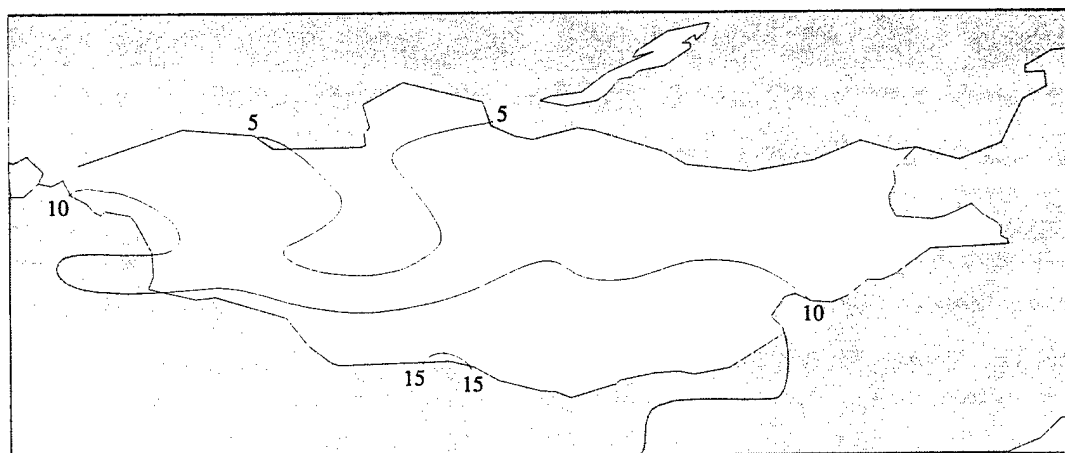


Figure 5-37. October Mean Maximum Temperatures (°C). The isopleths show the average of all high temperatures for the most representative month of the season.

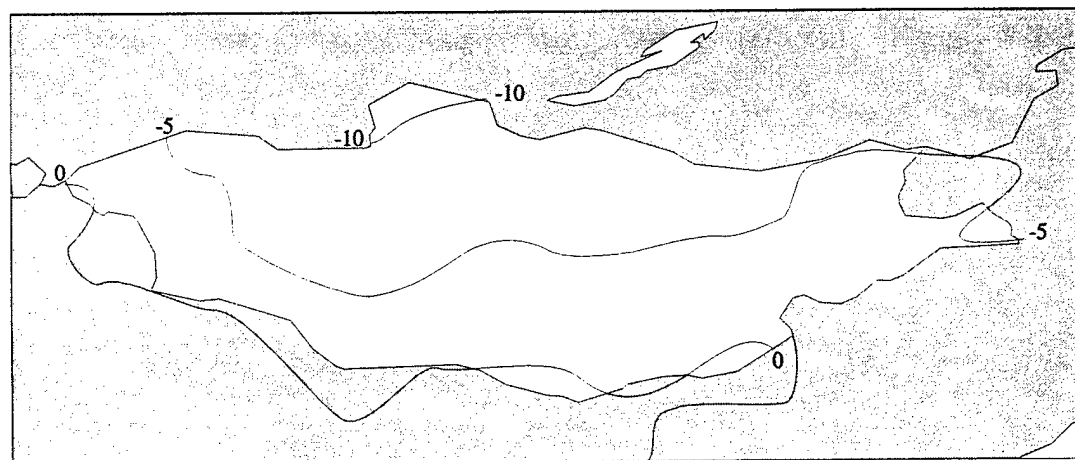


Figure 5-38. October Mean Minimum Temperatures (°C). The isopleths show the average of all low temperatures for the most representative month of the season.

MONGOLIA

Fall

September-October

Hazards. Aircraft icing is mainly restricted to altocumulus and altostratus layers found in the migratory frontal systems that pass through the region from the distant Atlantic Ocean moisture source. Low-level moisture is normally too scarce

to allow any more than a trace of icing. Light-to-moderate rime icing occurs in the light but nearly continuous snowfall found over the Altai, Hentiyn, and Hangayn mountains.

Trafficability. Mongolia is a country of high elevations with three major topographic areas. There areas include the following: (1) massive, forested, high mountains to the center, north, and west, (2) large basins between the mountains, and (3) an upland plateau across the south and east that consists of desert, semidesert, and upland steppe.

The mountains of the west are the highest and most rugged. The northern and central mountains have characteristically long, gentle slopes and crests covered with large, alpine pastures. The higher parts are very rough and rugged. With a few exceptions, movement in these mountains is unsuitable at all times because of the steep, rugged terrain. The exceptions are the gently sloping pastures. Here the soils are shallow to moderately deep and are mainly coarse to medium-grained or a mixture of both. Movement in these areas is fair when the soils are dry and not snow covered. When wet and not frozen, conditions are poor to fair because of soft and slippery surfaces.

In the intermontane basin areas, slopes vary. They are mostly gentle to rolling slopes. Soils

are predominantly deep and are a mix of coarse and fine-grained. When dry, movement conditions are fair to poor. When wet, the soils are soft and cause movement conditions to be unsuitable.

Most of the southern part of the country is rolling desert plain. This area is part of the great Gobi which is mainly stony desert. Some areas of dunes and sand plains occur in the west and south of this region and variously sized salt flats are scattered throughout. Soils are mainly coarse-grained. Fine-grained soils occur in salt flats. Movement conditions are fair to good most of the time except in sand dunes and in locations where the plain is broken by heavily dissected ranges.

The east part of Mongolia is rolling to hilly steppe plains that become flatter in the extreme east. Soils are moderately deep to deep and range from coarse to fine-grained. Movement conditions are fair to good except during the spring thaw. During this time, movement conditions vary from poor to unsuitable. Conditions depend on soil type. The best conditions are found in the areas with coarse-grained soils.

BIBLIOGRAPHY

- Barry, R. G., *Mountain Weather and Climate*, McGraw-Hill, Inc., New York, 1981.
- Boyle, J. S., and Chen, T. J., "Synoptic Aspects of the Wintertime East Asian Monsoon," *Monsoon Meteorology*, Oxford University Press, New York, 1987, pp. 125-160.
- Chang, J. H., "The Chinese Monsoon," *The Geographical Review*, 1971, pp. 370-395.
- Cheang, B. K., "Short- and Long-Range Monsoon Prediction in Southeast Asia," *Monsoons*, John Wiley and Sons, New York, 1987, pp. 579-606.
- Chenglan, B., *Aspects of the Climatology of China*, UHMET 84-04, Department of Meteorology, University of Hawaii, 1982.
- Chenglan, B., *Synoptic Meteorology in China*, China Ocean Press, Beijing, 1987.
- Domros, M., and Gongbing, P., *The Climate of China*, Springer-Verlag, Berlin, 1988.
- Flohn, H., "Contributions to a Meteorology of the Tibetan Highlands," *Atmospheric Science Paper No 130*, Department of Atmospheric Science, Colorado State University, Fort Collins, Colo., 1968.
- He, H. et al., "Onset of the Asian Summer Monsoon in 1979 and the Effect of the Tibetan Plateau," *Monthly Weather Review* Vol. 115, No. 9, 1987, pp. 1966-1995.
- Huschke, R., *Glossary of Meteorology*, American Meteorological Society, Boston, Mass., 1970, pp. 74 and 226. 1970.
- Joint U.S. Navy/U.S. Air Force Climatic Study of the Upper Atmosphere Vol. 1, January, NAVAIR 50-1C-1/AWS/TR-89/001, Naval Oceanography Command Detachment, Asheville, N.C., 1989.
- Joint U.S. Navy/U.S. Air Force Climatic Study of the Upper Atmosphere Vol. 4, April, NAVAIR 50-1C-4/AWS/TR-89/004, Naval Oceanography Command Detachment, Asheville, N.C., 1989.
- Joint U.S. Navy/U.S. Air Force Climatic Study of the Upper Atmosphere Vol. 7, July, NAVAIR 50-1C-7/AWS/TR-89/007, Naval Oceanography Command Detachment, Asheville, N.C., 1989.
- Joint U.S. Navy/U.S. Air Force Climatic Study of the Upper Atmosphere Vol. 10, October, NAVAIR 50-1C-10/AWS/TR-89/010, Naval Oceanography Command Detachment, Asheville, N.C., 1989.
- Landsberg, H.E., "Climates of Southern and Western Asia," *World Survey of Climatology*, Vol. 9, Elsevier Scientific Publishing Co., Amsterdam, 1981, pp 100-105.
- Lin, Z. and Zhang, J., *Climate of China*, John Wiley and Sons, Inc., Shanghai Scientific and Technical Publishers, New York, 1992.
- Malone, T., *Compendium of Meteorology*, American Meteorological Society, Boston, Mass., 1951, pp. 662-671.
- Marcal, G., *Climatology of Asia*, Air France, Paris, 1968.

Mintz, Y., "Very Long-Term Global Integration of the Primitive Equations of the Atmospheric Motion: An Experiment in Climate Simulation," *Meteorological Monographs* Vol. 8, No. 30, 1968, pp. 20-36.

Office of Technical Service, U.S. Department of Commerce, *Physical Geography of Tibet*, Washington D.C., 1959.

Ramage, C. S., "Role of the Himalayan-Tibetan Massif in the Monsoons," *WMO-No. 321*, World Meteorological Organization, Geneva, 1972, pp. 23-42.

Ramage, C. S., *Monsoon Meteorology*, Academic Press, New York, 1971.

Reiter, E., *Jet Stream Meteorology*, University of Chicago Press, Chicago, 1961.

Trewartha, G. T., *An Introduction to Climate*, Fourth Edition, McGraw-Hill, Inc., New York, 1968.

Wallace, J. M., and Hobbs, P. V., *Atmospheric Science, An Introductory Survey*, Academic Press, Inc., New York, 1977.

Waters, A., *Recurring Eastern Asiatic Synoptic Features*, 1WW TS 14, 1st Weather Wing Technical Services, Hawaii, 1967.

Yeh, T. C., and Ku C. C., "The Effect of the Tibetan Plateau on the Circulation of the Atmosphere and Weather in China," *Akademia Nauk Izvestiya, Seriya Geograficheskaya*, No. 2, Moscow, 1956, pp. 127-139.

Yihui, D., *Monsoons Over China*, Kluwer Academic Publishers, Netherlands, 1994.

Yoshino, M., et al, "Cold Wave and Winter Monsoon in East Asia; with Special Reference to South China," *Science Report*, Institute of Geoscience, University of Tsukuba, Section A Vol. 9, 1988, pp. 143-163.

Yoshino, M., "Some Aspects of the ITCZ and the Polar Frontal Zones over Monsoon Asia," *Water Balance of Monsoon Asia—A Climatological Approach*, University of Tokyo Press, Tokyo, 1971, pp. 87-108.

Zhang, J. and Lin, Z., *Climate of China*, John Wiley & Sons, Inc., New York, 1992.

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